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THE EFFECTS OF 4 WEEKS OF CONTRAST TRAINING VERSUS MAXIMAL STRENGTH TRAINING ON PUNCH FORCE IN 20-30 YEAR OLD MALE AMATEUR BOXERS

by

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A Research Project submitted in partial fulfilment of the requirements of the University of Chester for the degree of M.Sc. Sports Sciences (Strength and Conditioning)

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Signed …………………………………………………………….

Date ……………………………………………………………

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Abstract

The purpose of this study was to examine the effects of 4-week contrast and maximal strength training programmes on punch force in 20-30 year male amateur boxers. Twenty amateur boxers (mean age 24.5 ± 3.5 yr.) took part in the study and were randomly allocated into two groups. A contrast training group (n = 10) performed three sets of back squats interspersed with jump-squats and bench presses rotated with bench press throws. Exercises were alternated on a set-by-set basis and completed for three sets of three repetitions, twice weekly for four-weeks in place of two regular training sessions. A maximal strength training group (n = 10) performed back squats and bench presses for six sets of three repetitions, twice per week during the same time period. Punch force measurements analysed jab and rear-hand cross punches, utilising a *Herman Digital Trainer*. Additionally, muscular strength was assessed using 1-repetition maximum on 2 resistance exercises (back squat and bench press). All subjects were tested pre- and post-intervention. Two-way analysis of variance (ANOVA) with repeated measures and Bonferroni-adjusted post-hoc statistical analyses were adopted. It was found that the group x trials interaction was significant ($p < 0.0005$) for each punch type, with mean force values in the contrast training group (jab: 17 g, rear-hand cross: 19.7 g) increasing greater than the maximal strength training group (jab: 15.5 g, rear-hand cross: 17 g) at the study's conclusion. Similarly, significant improvements in muscular strength variables were observed in both groups for back squat (CT: 27.5%, MST: 18.8%) and bench press (CT: 26.9%, MST: 15.1%) exercises. It was concluded that contrast training is superior to maximal strength training at enhancing straight punching force and increasing muscular strength in male amateur boxers.

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Introduction:

Amateur boxing is a sport comprised of high-intensity offensive and defensive manoeuvres, interspersed with short recovery periods (Smith, 2006). Three, three-minute rounds are completed, divided by one-minute rest intervals. Within standard contests, attacking consistently with accumulative force often leads to victory (Pierce, Reinbold, Lyngard, Goldman & Pastore, 2006). The winner of a contest is the boxer who amasses the greatest quantity of points over three rounds, or if the referee halts the contest (knockout/corner stoppage). To score points, punches must land to the head or body of the opponent, above the beltline, with the knuckle section of the boxing glove. Contests are scored subjectively by five judges, with three scorecards selected at random to determine a winner. Contests are judged using a 10-point-must system (winner of the round receives ten points whilst the other competitor receives nine or less) with a boxer considered the winner based upon effective punching, defence and aggression. Although skill level is the main determinant (Davis, Leithauser & Beneke, 2014), the ability to throw repeated forceful punches significantly influences successful performance (Smith, 1998).

Since changing from computer to subjective scoring, contests place greater emphasis on straight punch force (Partridge, Hayes, James, Hill, Gin & Hahn, 2005) as the most successful strategy is to land high percentages of straight punches (Blower, 2007). In a typical amateur boxing contest, over 60% of punches are jabs or rear-hand crosses (Davis, Wittekind & Beneke, 2013). The jab effectively assesses distance whilst the rear-hand cross can be delivered with substantial force due to the influence of rear-leg drive and trunk rotation (Lenetsky, Harris & Brughelli, 2013).

As punch force (PF) is imperative within amateur boxing, recognising the significant elements that influence it would appear beneficial to boxing competitors. Filimonov, Koptsev, Husyanov & Nazarov (1985) examined 120 boxers (amateurs and professionals) to ascertain key determinants of PF, discovering the highest percentage originates from the rear-leg (38.46%), whereas trunk-rotation and arm-extension account for 37.42% and 24.12% respectively in experienced boxers. As muscular strength influences PF capabilities (Lenetsky, Harris & Brughelli, 2013), performing strength training, especially for the leg musculature, would appear beneficial in developing PF (Figure 1).

Figure 1. The role of strength & conditioning in performance (Jamieson, 2009; p.11).

Physiological enhancements from maximal strength training (MST) have been documented within various sports. As the purpose of any MST programme is to elevate athlete physical capacity (Bompa & Carrera, 2005), if correctly implemented, physiological improvements can be transferred to competitive performance. Although research (Cordes, 1991) demonstrates boxers can benefit from MST, boxing as a sport is reluctant to implement it (Turner, Baker & Miller, 2011). This reluctancy stems from misconceptions such as increased body mass and diminished aerobic efficiency (Ebben & Blackhard, 1997). Previous authors (Getke & Digtyarev, 1989; Solovey, 1983) have utilised MST with boxers, with Solovey (1983) finding MST enhanced PF without increasing body mass. However, none have employed a more contemporary method known as contrast training (CT) on boxing performance.

Termed as the ability to produce maximal force against resistance (Kraemer & Ratamess, 2004), MST is augmented through the use of weighted equipment such as free-weights due to heavy-resistance training producing paramount strength adaptations (Stone, Stone & Sands, 2007). To achieve adaptation, MST should be performed with loads of >85% one-repetition maximum (1-RM) to augment neural stimulation (Bompa, Di Pasquale & Cornacchia, 2003). Performing MST with loads >85% 1-RM can improve athletic ability through enhanced force-production and rate of force development (RFD) (Zatsiorsky & Kraemer, 2006), resulting from elevated central nervous system (CNS) stimulation (Gabriel, Kamen & Frost, 2006).

Described as the ability to produce substantial concentrations of force rapidly (Komi, 2003), power in addition to strength also significantly influences boxing success as boxers need to produce force swiftly (e.g. jab) (Jamieson, 2009). However, previous authors (Mangine, Ratamess, Hoffman, Faigenbaum, Kang & Chilakos, 2008; Rippetoe & Kilgore, 2009) suggest combining strength and power/ballistic exercises is superior at optimising performance than one training method alone, thus, CT was established.

Defined as alternating heavy and light resistance-training loads on a set-for-set basis (Duthie, Young & Aitken, 2002), CT protocols enhance force greater than strength/power in isolation (Esformes, Cameron & Bampouras, 2010) (see Appendix A). In terms of strength improvements, Rahmi and Behpur (2005) compared the effects of MST, plyometric training and CT on lower-body strength (back squat 1-RM) in college males. Results demonstrated CT (64 kg) enhanced strength in all exercises greater than MST (49 kg) and plyometric (29 kg) groups after 6-weeks. However, the study lacked any training for upper-body musculature, and its effects on this important component of boxing are unknown. In terms of power, Scott & Docherty (2004) demonstrated 20% and 23% improvements in counter-movement and standing long-jump performances respectively in male athletes following >85% 1-RM back squats (CT protocol).

Sáez de Villarreal, Requena, Izquierdo and Gonzalez-Badillo (2013) determined that CT elevated strength and power greater than other training methods. The study researched the impact of various resistance-training methods on squat 1-RM, 30-metre sprint performance and concentric squat-velocity of sports-science students over 7-weeks. Significant improvements surfaced in all groups, with CT (20%) being superior to all other groups, including MST (11%) at elevating all performance variables (Figure 2). These improvements resulted from CT optimising neuromuscular recruitment whilst taking 'advantage of post-activation potentiation (PAP)' (Jones, Bampouras & Comfort, 2013; p.11).

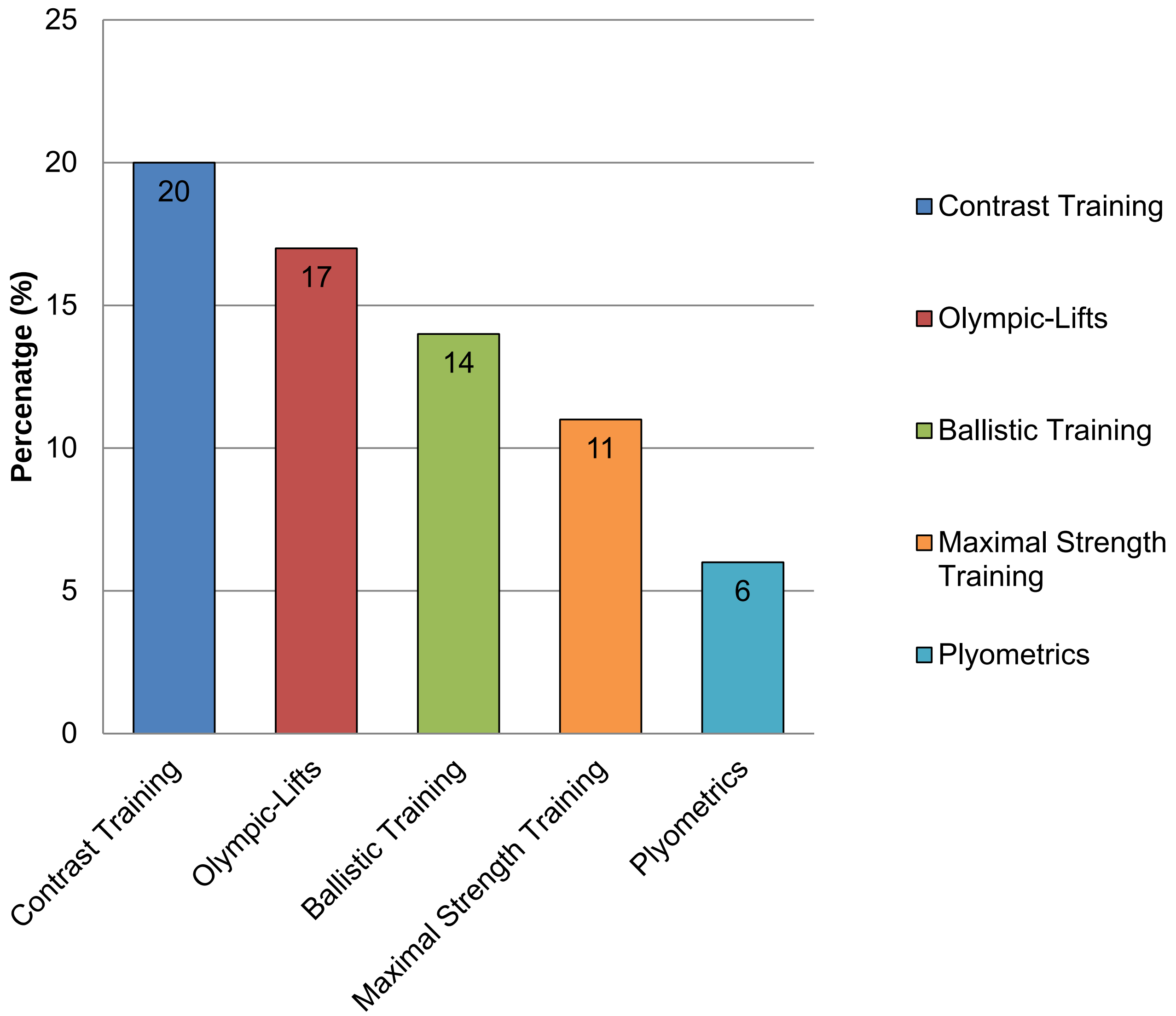

Figure 2. Sáez de Villarreal, Requena, Izquierdo and Gonzalez-Badillo (2013) research data.

PAP, defined as the ‘phenomenon where previous muscular contractions enhance subsequent explosive force-generation’ (Gilbert & Lees, 2005; p.1576), arises from elevated neural-activation. This includes greater motor-unit recruitment (Hrysomallis & Kidgell, 2001) and light-chain phosphorylation (Chiu & Barnes, 2003), resulting from high-intensity (>87% 1-RM) strength training (Farup & Sorensen, 2010). This subsequently initiates the sarcoplasmic reticulum to release Ca^{2+} molecules and bind to calmodulin (Jones, Bampouras & Comfort, 2013). Thus, myosin heads drift away from filament surfaces, allowing an easier connection with actin filaments during the subsequent power exercise (Zhao & Craig, 2003).

Consequently, CT, which optimises PAP, provides greater motor-unit availability in subsequent muscular contractions, enhancing force potential (Crewther, Kilduff, Cook, Middleton, Bunce and Yang (2011). Thus, CT is beneficial to athletes competing in sports where RFD is essential, such as boxing (Olsen & Hopkins, 2003). As previous research examining CT influence on PF is scarce, the purpose of the present study is to determine if a CT intervention enhances PF greater than MST in male amateur boxers.

The hypotheses of the present study were:

H_1 – Contrast training will enhance punch force to a greater degree than maximal strength training in amateur boxers.

H_0 – Contrast training will not enhance punch force to a greater degree than maximal strength training in amateur boxers.

Methodology:

Participants

Twenty male participants were recurited from the membership of the New Era Amateur Boxing Club (Northwich, Chehire) all 20-30 years of age, with at least two years of boxing experience (Table 1).

Table 1. Characteristics of present study participants.

	Contrast training (*n* = 10)	Maximal strength training (*n* = 10)
Age (years)	26.2 ± 3.1	26.1 ± 1.8
Stature (cm)	181.9 ± 5.9	177.8 ± 5.8
Body mass (kg)	86.1 ± 6.9	76.2 ± 8.5
Boxing experience (years)	5.1 ± 1.3	5.4 ± 2.4

Note: Values expressed as mean ± standard deviation.

All participants were known to the researcher and were approached to volunteer via one-to-one conversations. Each received a participant information sheet (see Appendix B) and provided written informed consent (see Appendix C). Additionally, participants were screened for health status prior to testing via a physical activity readiness questionnaire (PAR-Q) (see Appendix D). The sample size enabled two groups of ten randomly allocated boxers to be formed; ten placed into the contrast training (CT) group and the other into the maximal strength training

(MST) group. A sample size calculation was completed via G*Power software version 3.1.9 (Faul et al., 2009) using appropriate input parameters (effect size = 1.8, significance level = 0.05, power = 0.8). Effect size was calculated from Shoepe, Ramirez, Rovetti, Kohler and Almsted (2011), who demonstrated strength increases of 16 ± 8.5 kg in novice athletes after 4-weeks of a 24-week training programme, consisting of back squats and bench presses. The sample size calculation revealed a total sample of four subjects to achieve significant results (see Appendix E). As all participants were novices (see Appendix F), mobility assessments (see Appendix G) were completed prior to the study to determine their back squat and bench press proficiency, allowing movement stability and efficiency assessment (Cressey & Fitzgerald, 2008).

Design

The study had an experimental, repeated measures design to assess training effects on PF. Previous studies (e.g. Cordes, 1991; Solovey, 1983) were between 8- and 16-weeks in duration, however the present study was 4-weeks as strength adaptations are most prevalent within this time-period (Hickson, Hidaka & Foster, 1994) due to enhanced neuromuscular efficiency (Folland & Williams, 2007). Familiarisation sessions were not completed for resistance training as all participants had prior experience with the exercises utilised within the present study. The study measures (body mass, 1-RM and PF scores) were collected personally by the researcher who was present at all testing and training sessions. The dependent variables were PF and 1-RM (back squat and bench press), measured via the Herman Digital Trainer (HDT) PF and 1-RM strength tests. The independent variable was strength training procedure (CT and MST). The research design is presented in Figure 3:

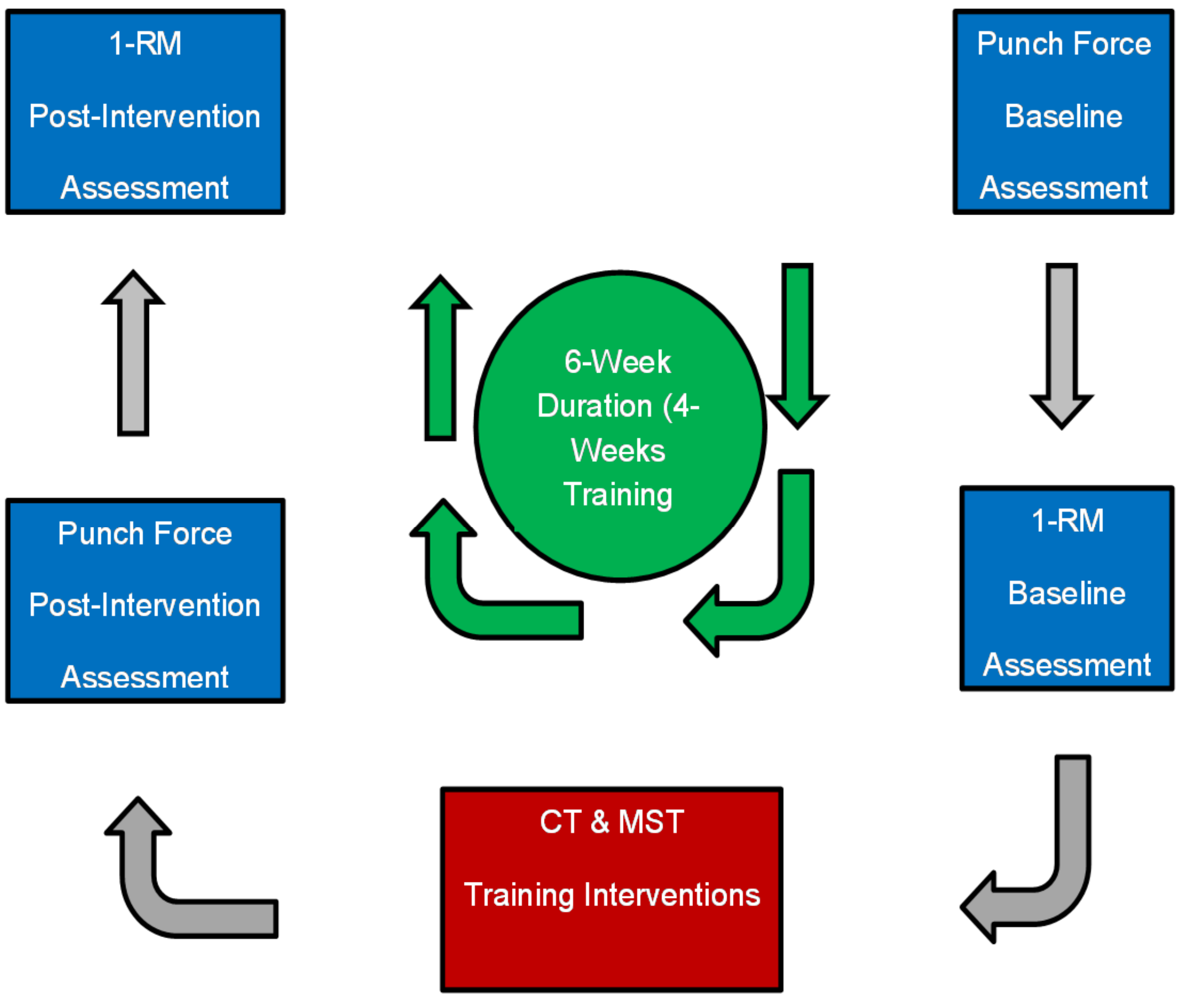

Figure 3. Schematic of Study Design.

Following protocols designed by Storen, Helgerud, Stoa and Hoff (2008), if any participants completed less than 70% of the eight total training sessions, their data was taken out of the statistical material. The 70% limit was put in place as this is the minimum training threshold required for adaptations to occur from training within research (Kraemer & Ratamess, 2004). As it happened, no participants completed less than the required number of training sessions.

Procedures:

An effective intensity for enhancing maximal strength is >85% 1-RM due to optimal neuromuscular stimulation associated with this intensity (Bird, Tarpenning & Marino, 2007). Therefore strength training loads were 90% 1-RM to allow three repetitions to be completed for both CT and MST groups as loads >85% 1-RM are necessary to elicit PAP (Matthews, O'Conchuir & Comfort, 2009). For ballistic exercises, 40% 1-RM loads were used as this intensity induces greater force-output compared to 60% and 80% 1-RM respectively (McBride, Triplett-McBride, Davie & Newton, 2002).

Three repetitions were completed for all exercises to maximise muscular strength and power (Brewer, 2008) whilst six sets were implemented for both training groups to ensure identical training volume in addition to optimising strength/power development (Carpinelli & Otto, 1998). Two-weekly sessions were undertaken, providing sufficient stimulus for resistance training adaptations without disrupting sport-specific skill development (Peterson, Rhea & Alvar, 2004). Four-minute recovery periods were included as this enhances neuromuscular recovery in MST

(Gambetta, 2007) and CT (Kilduff et al., 2007). Additionally, Schwanbeck, Chilibeck and Binsted (2009) suggest free-weights (e.g. barbells and dumbbells) are optimal for optimising resistance training adaptations as average muscle electromyography (EMG) activity is 43% greater when using free-weights compared to resistance machines. Consequently, all exercises included within the present study were categorised as free-weight resistance exercises.

For testing PF, a Herman Digital Trainer (HDT) was utilised. This device uses micro accelerometers via tri-axial measurements (X axis range = ± 40 g, Y axis range = ± 40 g and Z axis range = ± 50 g), allowing force-scores to be recorded in response to punch impacts. The accelerometer was attached to a circuit board which included a microprocessor which retained an analogue-to-digital (A/D) converter, flash memory and random access memory (RAM). HDT sensors sampled data at a rate of 100 Hz which was smoothed via a four-pole low-pass filter. The greatest score post-impact was considered peak-force. Upon impact, a multiplexer recognised the desired analogue signal, which was transmitted to digital signals by the A/D converter and collected by the RAM. A signal-processor then sent processed results to a controller unit. Force sensors were connected to a HDT controller-unit by an asynchronous sequential communication. The HDT controller unit both stored PF data and displayed it in digital form.

The HDT was tested for its reliability using typical error and coefficient of variation (CV) statistics for three repeat trials. This was completed as current research demonstrating PF reliability using a HDT is non-existent. The procedure utilised the same twenty participants as the research study. Each participant completed 3 x 3 maximal jab and rear-hand cross punches with each set of punches completed within a ten-second time frame. Ten minute recovery periods were provided between sets to ensure maximal recovery. This procedure was completed three times, with 24 hours separating each test.

All participants were provided with a standardised instruction from the lead researcher. This instruction was to 'punch the bag as hard as possible whilst maintaining technique'. This instruction was delivered to prevent punches of diminished technique or of a different variety (e.g. hook, uppercut) being completed in attempts to get higher PF results.

Participants were allowed up to ten practice punches before punch force scores were recorded to provide habituation with the testing procedure. Participants were not provided with any performance feedback during the testing procedure to prevent knowledge of results influencing PF scores.

1-RM Assessment

Preceeding training interventions, participant back squat and bench press 1-RM were tested to determine muscular strength. A warm-up was completed prior to 1-RM tests (see Appendix H) to accelerate introductory activity processes and foster performance improvements (Verkhoshansky & Verkhoshansky, 2011). For 1-RM testing, participants performed back squats and bench presses for ten repetitions at a load approximately 50% of 1-RM based on pilot work, with load subsequently increased in small increments. The procedure of Storen, Helgerud, Stoa and Hoff (2008) was utilised as the researcher had prior experience using this successfully with athletes (Table 2 and Appendix I). Attempts were made to reach participant 1-RM swiftly to prevent fatigue and avoid compromising their technique (Cardinale, Newton & Osaka, 2011).

Table 2. Storen, Helgerud, Stoa and Hoff (2008) one-repetition maximum (1-RM) testing procedure.

Load	***Repetitions***	***Rest Periods***
50% of 1-RM	10	3 minutes
60% of 1-RM	5	3 minutes
70% of 1-RM	3	3 minutes
80% of 1-RM	1	3 minutes
Weight increased by 2.5 - 5 kg	1	5 minutes
Continue until reaching 1-RM	1	5 minutes

Note: The athlete performed each exercise for ten repetitions at a load approximately 50% 1-RM based off previous test results (athlete tested four months prior) with load subsequently increasing in small increments.

Punch Force Assessment

PF was tested using the aforementioned HDT device which was secured at the rear side of a 20 kg punch bag, behind an impact point located at a height of 179 cm. This height was calculated by determining the mean height of all twenty participants (179 ± 6.2 cm) to ensure significant PF could be generated by everyone. The HDT was firmly attached using PVC tape to guarantee minimal movement when testing. Prior to testing, all participants performed a ten-minute warm-up consisting of skipping and shadow boxing. The punch bag used was made of cow-hide leather, filled with a high-density foam and was safely secured to a wall bracket with a stainless steel heavy-bag chain. Each participant wore the same ten-ounce Adidas competition boxing gloves over regular hand bandages.

Two punches were assessed (Table 3) and thrown from an orthodox stance (left hand as lead hand, right hand as rear hand) as this was the preferred stance of all participants. For each test, participants were instructed to strike the punch bag using a single, maximum effort punch. Participants completed ten punches (five jabs, five rear-hand crosses) with three minutes of recovery between each to ensure maximal force on each attempt (Gastin, 2001). All punches were supervised by the same researcher and a level three amateur boxing coach (>12 years' experience) at New Era Amateur Boxing Club.

Table 3. Punch types to be utilised in conjunction with the HDT for measuring punch impact force (Thomson, Lamb & Nicholas, 2013).	
Punch	**Description**
Jab	A straight punch from the lead hand that moves along the sagittal plane (the central visual line) from anterior to posterior
Rear-hand cross	A straight punch from the rear hand that moves along the sagittal plane (the central visual line) from anterior to posterior

Training programme interventions

Participants within the CT and MST groups then participated in a four-week training programme, consisting of two-weekly sessions, 72 hours apart (Table 4 and Appendix I). Each session lasted approximately 80 minutes and replaced two of the participants' regular weekly training sessions to prevent the risk of overtraining. The CT group completed three repetitions of back squats at 90% 1-RM alternated with three repetitions of jump-squats at 40% 1-RM, repeated three times. This procedure was replicated for bench press (90% 1-RM) and bench press throws (40% 1-RM) respectively. MST participants performed six sets of three repetitions of 90% 1-RM back squats followed by six sets of three repetitions of 90% 1-RM bench presses. All participants received four-minute recovery periods between sets. Once both training programmes were concluded, PF, back squat 1-RM and bench press 1-RM tests were repeated to determine if PF and/or 1-RM scores changed as a result either resistance training method.

Table 4. Contrast training and maximal strength training intervention schdule.		
Week Day	*Training intervention*	Time performed
Monday	CT	7pm
Tuesday	MST	7pm
Wednesday	---	---
Thursday	CT	7pm
Friday	MST	7pm

If a participant was able to complete four repetitions with a 90% 1-RM load when performing back squats/bench presses, the load was increased by 2.5 kg for the subsequent set to ensure only three repetitions could be completed. For the contrast training group, if strength exercise load increased, then power exercise load was also elevated in accordance with strength loads to maintain exercise intensity (40% 1-RM).

Due to use of heavy free-weights and resistance training exercises, injury was a potential risk existing within the training interventions and 1-RM testing procedures. This risk was managed through the use of two experienced ‘spotters' who supervised all sessions along with the lead researcher to ensure safe resistance-training environments. All participants were familiar with back squats and bench presses, however were unfamiliar with loads >60% 1-RM. Consequently, the researcher administered all training sessions to ensure exercises were performed safely and correctly.

Some participants experienced delayed-onset muscular soreness (DOMS) due to the resistance training intensity. However strength and/or power is not affected by this training effect (Vaile, Gill & Blazevich, 2007) and was managed through the supply of resistance training recovery guides (see Appendix J).

Statistical Analysis

Descriptive statistics (mean ± SD) were generated for all dependent variables and their distributions checked for normality and equal variance using Shapiro-Wilk and Levene tests, respectively (see Appendix K). As these conditions were met, parametric tests were used to analyse the variability of measures. A 2-way (treatment x time) repeated measures analysis of variance (ANOVA) was conducted to reduce type 1 error risks associated with multiple comparisons (Howell, 1997), followed by post-hoc Bonferroni-adjusted independent & paired samples t-tests to determine where specific variable means differed. Level of significance was set at P

= 0.05 in line with convention for the ANOVA tests (Atkinson & Nevill, 1998) and P = 0.25 for the post-hoc t-tests. Statistical analyses were performed using IBM SPSS software version 21. Adiitonally, magnitude-based inferences, as suggested by Batterham and Hopkins (2006), were computed to identify meaningful differences between training groups whilst quantifying practical significances with calculations completed using a predesigned spreadsheet (Hopkins, 2006).

Results:

Body Mass

Body mass demonstrated a significant Trial effect (F = 20.4, P < 0.05), with post-intervention overall values being higher than pre-intervention for both (see Appendix L). The body mass Group effect was non-significant (F = 7.3, P = 0.14), as was the Trial x Group interaction (F = 0.0, P = 1.00).

Table 5. Training group comparisons of body mass, 1-RM strength and punch force from pre- to post-training.

	Contrast training (n = 10)		Maximal strength training (n = 10)	
	Pre-training	Post-training	Pre-training	Post-training
Body mass (kg)	86 ± 6.9	86.5 ± 6.9	76.1 ± 8.5	76.6 ± 8.5
Back squat 1-RM (kg)	85.3 ± 13.1	108.8* ± 13.4	86.1 ± 10.4	102.3* ± 10.9
Bench press 1-RM (kg)	78 ± 12.1	99* ± 9	82.3 ± 11.6	94.8* ± 12.1
Jab punch force (g)	14.1 ± 1.8	17.1* ± 2.2	13.8 ± 1.6	15.5* ± 1.6
Rear-hand cross punch force (g)	16.3 ± 2.3	19.7* ± 2.8	15.2 ± 1.4	17* ± 1.3

Note: Values expressed as mean ± standard deviation. *Indicates a significant difference ($P < 0.05$) from pre- to post-training.

Punch Force

The jab demonstrated a significant Trial effect ($F = 534.7$, $P < 0.05$), as did rear-hand cross ($F = 381.1$, $P < 0.05$), with post-intervention overall values being higher than pre-intervention for both (see Appendix M for factor means). Whilst for both variables the Group effect was non-significant ($P > 0.05$), the Group x Trials interaction was (jab: $F = 39.6$, $P < 0.05$; rear-hand cross: $F = 34.4$, $P < 0.05$; Figure 4). Post-hoc analysis revealed that CT participants demonstrated significant jab ($t = -16$, $P < 0.05$) and rear-hand cross ($t = -14.4$, $P < 0.05$) improvements pre-to-post, as did the MST participants ($t = -20.7$, $P < 0.05$ and $t = -14.4$, $P < 0.05$ for jab and rear-hand cross, respectively). Furthermore, no significant jab differences were observed between groups post-training ($t = 1.7$, $P = 0.95$), whereas rear-hand cross was ($t = 2.5$, $P = 0.02$) significantly different.

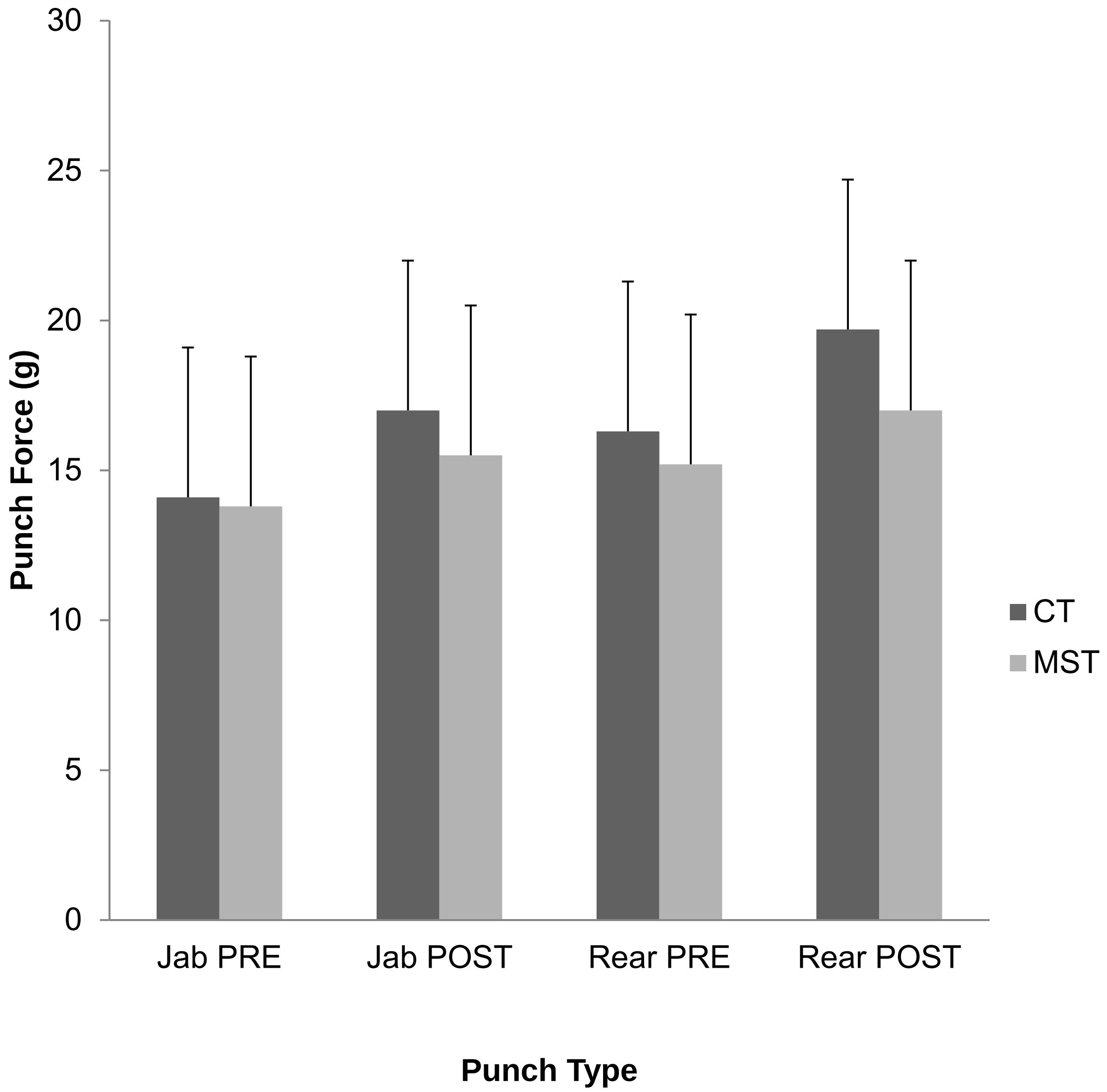

Figure 4. Punch performance of participants, throwing jab and rear-hand cross punches, measured in g.

One-Repetition Maximum

The back squat demonstrated a significant Trial effect ($F = 598.2$, $P < 0.05$), as did bench press ($F = 160.9$, $P < 0.05$), with post-intervention overall values being higher than pre-intervention for both (see Appendix N). Whilst for both variables the Group effect was non-significant ($P > 0.05$), the Group x Trials interaction was (back squat: $F = 20.2$, $P < 0.05$; bench press: $F = 10.3$, $P < 0.05$; Figure 5). Post-hoc analysis revealed that CT participants demonstrated significant back squat ($t = -25.3$, $P < 0.05$) and bench press ($t = -8.3$, $P < 0.05$) improvements pre-to-post, as did the MST participants ($t = -12.1$, $P < 0.05$ and $t = -15$, $P < 0.05$ for back squat and bench press, respectively). Additionally, no significant back squat ($t = 1.2$, $P = 0.27$) or bench press ($t = 0.8$, $P = 0.40$), differences were observed between groups post-training.

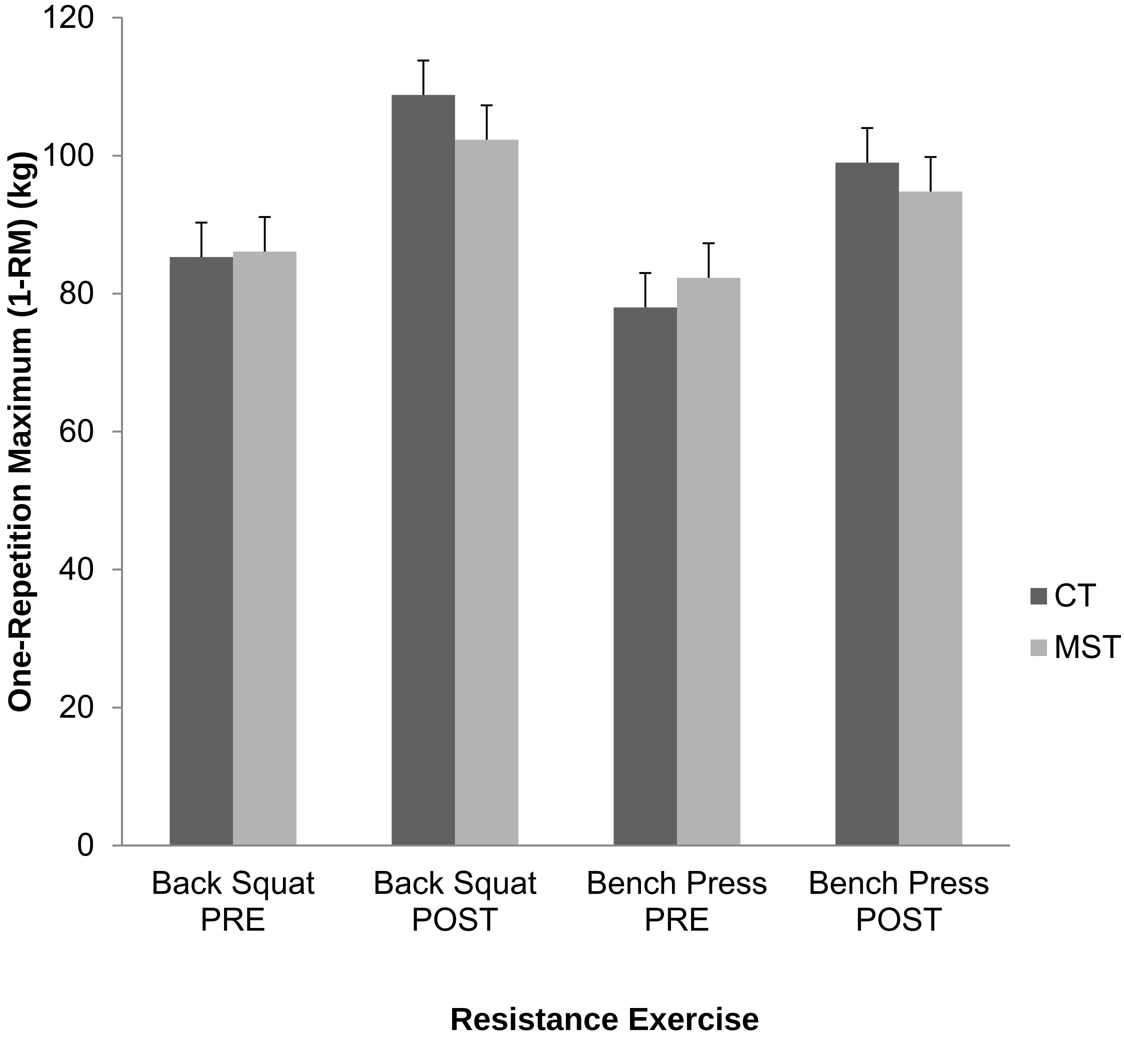

Figure 5. One-repetition maximum (1-RM) performance of participants, measured in kg.

Magnitude-Based Inferences

Differences in body mass of both training groups, according to probabilistic inferences on the observed effect size, were determined most likely trivial (CT = 0.06: ± 0.01 kg, MST = 0.05: ± 0.04 kg) from pre- to post-training (Table 6).

CT group jab (1.41: ± 0.08 g) and rear-hand cross (1.26: ± 0.08 g) punch forces, from pre- to post-training, were considered most likely large/beneficial increases. Additionally, MST jab (0.91: ± 0.04 g) and rear-hand cross (1.11: ± 0.07 g) results were also considered most likely large/beneficial increases (Table 6).

Furthermore, based on probabilistic inferences of effect size, CT was most likely to confer large benefits in 1-RM back squat (1.56: ± 0.11 kg) and bench press (1.50: ± 3.3 kg) strength from pre- to post-training. Similarly, MST group differences in BS (1.35: ± 0.2 kg) and BP (0.93: ± 0.11 kg) 1-RM scores from pre- to post-training were also deemed most likely large/beneficial increases (Table 6).

Table 6. Statistical summary of the differences in performance variables between the contrast training and maximal strength training groups.

Performance Variable	Training Group	Degrees of freedom (*df*)	Difference (90% confidence limits)	%Difference (pre- to post-training)	Interpretation
Body mass (kg)	Contrast	9	0.06 (±0.01)	0.5%	Most likely trivial increase
	Maximal strength	9	0.05 (±0.04)	0.6%	Most likely trivial increase
Jab punch force (g)	Contrast	9	1.41 (±0.08)	21.1%	Most likely large increase
	Maximal strength	9	0.91 (±0.04)	12.4%	Most likely large increase
Rear-hand cross punch force (g)	Contrast	9	1.26 (±0.08)	20.4%	Most likely large increase
	Maximal strength	9	1.11 (±0.07)	11.7%	Most likely large increase
Back squat 1-RM strength (kg)	Contrast	9	1.56 (±0.11)	27.5%	Most likely large increase
	Maximal strength	9	1.35 (±0.2)	18.8%	Most likely large increase
Bench press 1-RM strength (kg)	Contrast	9	1.50 (±0.33)	26.9%	Most likely large increase
	Maximal strength	9	0.93 (±0.11)	15.1%	Most likely large increase

Note: Threshold probabilities for a substantial effect were: <0.5% most unlikely, 0.5–5% very unlikely, 5–25% unlikely, 25–75% possibly, 75–95% likely, 95–99.5% very likely, >99.5% most likely. Thresholds for the magnitude of the observed change in each dependent variable were determined as the within-participant SD x 0.3, 0.9 and 1.6 for a small, moderate and large effect, respectively. Cohen's *d* effect sizes were classified as: trivial <0.2, small 0.2-0.6, moderate 0.6–1.2, large 1.2–2.0, and very large >2.0 (Hopkins, 2006).

Discussion:

The purpose of this study was to determine if CT could enhance PF greater than MST. Although not statistically significant, results revealed that a 4-week CT programme had a greater effect upon PF than an MST programme in amateur boxers. Furthermore, CT participants augmented upper- and lower-body muscular strength to a greater degree than MST participants. CT and MST groups also exhibited non-significant, most likely trivial body mass increases following the training interventions.

Post-training, CT and MST body mass was considered significantly different as a result of both training interventions, whilst a Trials x Group interaction was deemed non-significant. These results are the likely consequence of deviating mean values between groups at baseline (CT: 86 ± 6.9 kg; MST: 76.1 ± 8.5 kg). The non-significant interaction was reinforced by magnitude-based inferences tests, which determined CT (0.05 ± 0.01) and MST (0.06 ± 0.04) body mass increases post-training were most likely trivial. The trivial increases relate to Solovey (1983), who discovered non-significant body mass increases following a 12-week MST programme in amateur boxers. However, no statistical information is available from this study, prompting uncertainty as to the accuracy of the results.

Furthermore, the presents study's results were in accordance with Shoepe et al.'s (2011), who exhibited non-significant ($P < 0.05$) body mass increases at the 4-week period of a 24-week strength training programme. The present study's trivial body mass increases were likely influenced by augmented neuromuscular efficiency rather than muscular hypertrophy (Cormie, McGuigan & Newton, 2011) as the most significant physiological adaptations occur in the first 2-4 weeks of resistance training (Kim, Dear, Ferguson, Seo & Bemben, 2011).

A significant Group x Trial interaction was observed for jab, although post-hoc analysis revealed non-significant differences between groups post-intervention. However, notable differences between the means were noted, possibly resulting from the small sample sizes within the present study (10 per group). Additionally, both groups exhibited large, most likely beneficial effects post-training, with CT (1.41 ± 0.08) improving to a greater degree than MST (0.91 ± 0.04). Furthermore, CT exhibited significant, beneficial rear-hand cross effects post-training compared to MST (1.26 ± 0.08 and 1.11 ± 0.07, respectively).

Previous literature investigating PF using a HDT has not been reported, therefore, it is difficult to determine whether the presents study's results correlate with other studies. Of the studies that exist, only Topal, Ramazanoglu, Yilmaz, Camliguney and Kaya (2011) examined striking force using the same HDT as the present study, discovering the HDT device was a reliable measure of striking force in 24 taekwondo athletes performing elastic band-resisted strikes. Additionally, Broker and Crowley (2002) analysed PF using an accelerometer placed within a punch bag, however, no statistical results were revealed and the device was deemed unreliable due to the inertia and movement of the punch bag during impact. The HDT device used in the present study was also fixed to a punch bag, but unlike Broker and Crowley (2002), was tested for its reliability using typical error (TE) and coefficient of variation (CV) statistics for three repeat trials (see Appendix O). The resulting TE and CV measurements were 0.16 (1.01%) for jab and 0.17 (0.96%) for rear-hand cross, indicating good repeatability between punch force trials (Dyson, Smith, Martin & Fenn, 2007), corroborating with Topal et al. (2013).

Although literature using the HDT is scarce, research has been completed using various different devices. Smith, Dyson, Hale and Janaway (2000) tested PF of elite, intermediate, and novice boxers, utilising a wall-mounted force plate, discovering elite boxers generated 4,800 ± 227 N with intermediate and novice boxers generating 3,722 ± 133 and 2,381 ± 116 N, respectively. Meanwhile, Pierce et al. (2006) ascertained peak PFs of 3,554 N, noticeably less than Smith et al. (2000) and Atha, Yeadon, Sandover and Parsons (1985) (4,096 N). These result disparities are exacerbated by the present study's findings, due to the conflicting PF measurement units (g and Newtons).

The present study only had access to the HDT device (measurements in g), rather than a piezoelectric force sensor used in previous studies (measurements in Newtons) (Atha et al., Girodet, Vaslin, Dabonneville & Lacouture 1985; Smith et al, 2000). As g are generally regarded as an acceleration measurement (1 g = 9.81m/s2) (Umeda & Ueda, 1990), the HDT's validity as a PF assessment device requires further examination. Consequently, although exhibiting significant improvements post-intervention, the present study's PF results should be observed with caution, due to the HDT accuracy currently lacking validity (Topal et al., 2013).

Greater PF was observed for rear-hand cross punches (CT = 19.7 g; MST = 17 g) compared to jab punches in both groups (CT: 17 g; MST: 15.5 g). These findings correlate with Dyson et al. (2007) and Karpilowski, Nosarzewski and Staniak (1994), who discovered boxers produced significantly greater mean PF values for rear-hand punches compared to lead-hand punches. However, Dyson et al. (2007) failed to examine PF alterations following resistance training whilst Karpilowski et al. (1994) only examined one boxer, whilst failing to provide clarification for the greater rear-hand PF exhibited. Piorkowski, Lees and Barton (2011) deem differences in jab and rear-hand cross PF to be the result of the additional force generated by the rear-leg, body rotation as well as the distance over which rear-hand punches are thrown. Furthermore, rear-hand punches are influenced by extension at the ankle, knee and hip, in addition to considerable rectus femoris and biceps femoris recruitment, unlike lead-hand punches (Lockwood & Tant, 1997).

The present study also established that both training programmes enhanced back squat and bench press 1-RM significantly ($P < 0.05$), with CT (BS: 27.5%; BP: 26.9%) exhibiting greater improvements post-training than MST (BS: 18.8%; BP: 15.1%). Although significant Trial and Trial x Group effects were observed, post-hoc analysis revealed non-significant differences between groups post-intervention for both back squat and bench press 1-RM. This may be related to present study's CT ballistic exercise intensity. Although McBride et al. (2002) discovered loads of 40% 1-RM induced peak force-outputs, the present study's participants may have required varying loads to achieve peak-force as PAP is augmented using loading intensities between 30% and 60% 1-RM (Jones et al., 2013). This judgment is corroborated by Mangine et al. (2008), who established non-significant back squat 1-RM differences between MST and CT groups following 8-weeks of training, using ballistic exercises loads of 50% 1-RM. However, this was concluded to be the result of contrasting back squats with high pulls, with the authors suggesting the high pull exercise did not emulate the back squat movement pattern adequately to elicit PAP. This insinuates that biomechanical factors (i.e. movement patterns) which exemplify certain exercises (i.e. back squat and jump-squat) should be considered when using CT to ensure the specificity principle is adhered to, optimising potential adaptation.

CT participants within the present study exhibited a greater back squat 1-RM effect (1.56 ± 0.11) post-training than the MST participants (1.35 ± 0.2), correlating with Cormie, McCaulley and McBride (2007) who discovered significant ($P < 0.05$) back squat 1-RM enhancements resulting from CT. The present study's most likely beneficial back squat augmentation for the CT group is perhaps associated with the additional power-oriented exercises, of which enhance strength performance through more forceful muscular-contractions compared to MST alone (Fatouros, Jamurtas & Leontsini, 2000). The present study also discovered most likely large effects for bench press 1-RM in CT (1.50 ± 0.33) and MST (0.93 ± 0.11) groups, with CT displaying superior enhancements. These improvements draw parallels with CT (12.2%) and MST (7.4%) bench press 1-RM improvements presented by Mangine et al. (2008).

One plausible explanation for the superior CT 1-RM results in both 1-RM tests was the CT subjects being exposed to various loads across the force-velocity curve (Figure 6) (Haff, Whitley & Potteiger, 2001). The MST intervention exercises, despite significantly improving force, were executed at a relatively low velocity due to the use of a high loading protocol (90% of 1RM). Meanwhile, the CT Intervention included high-force exercises in addition to high-velocity movements, which when combined, enhance explosive performance (Duthie et al., 2002).

Figure 6. Exercise loads based on the force-velocity curve (Lasnier, 2012; p.1).

Previous authors (Brandenburg, 2005; Hrysomallis & Kidgell, 2001; Talpey, Young & Saunders, 2014) failed to discover performances increases from CT in both the upper- (Hrysomallis et al., 2001) and lower-body (Talpey et al., 2014). However, both of these studies utilised 5-RM loading intensities, which have been previously illustrated to induce fatigue within CT programmes (Jones et al., 2013). Furthermore, Talpey et al. (2014) implemented two minute recovery periods between strength and ballistic exercises, which can reduce peak-force and RFD in CT protocols due to neuromuscular fatigue (Gouvêaa, Fernandesa, Césara, Silvaa & Gomesa, 2013). The disparities in results between CT studies confirms the necessity for further research to examine the influence of PAP on specific-performance variables (i.e. boxing PF) in addition to established performance qualities (i.e. vertical jump) to determine if CT enhances sport-specific performance. Although various studies have examined CT effects upon conventional performance variables, current literature lacks evidence to accurately support or dispute the relationship between CT and PF.

Matthews and Comfort (2008) hypothesised that CT improved PF in boxers, with the present study substantiating this proposal. However, this study did not assess PF (pre- or post-training) and utilised cable-resisted punches rather than traditional resistance exercises, of which may negatively influence punching technique. Nevertheless, as muscular strength in boxers is not improved through sporting practice alone (Wong, 2010), increasing upper- (Liossis, Forsyth, Liossis & Tsolakis, 2013) and lower-body strength (Turner, 2009) can augment PF dramatically (La Bounty, Campbell, Galvan, Cooke & Antonio, 2011).

It cannot be discounted that the present study's CT intervention consisted of only two exercise-pairings. Although two exercise-pairings can improve force production, a lack of training variation can cause adaptations to plateau (Austin & Mann, 2012). Subsequently, future research may look to assess different CT exercise-pairings and their subsequent influence on PF. For example, as medicine-ball shot-puts improve hip, knee and ankle drive explosiveness (Terzis, Georgiadis, Vassiliadou & Manta, 2009) in a boxing-specific movement pattern (Obmiński, Borkowski & Sikorski, 2011), 85-90% 1-RM dumbbell push-presses contrasted with medicine-ball shot-puts may enhance PF greater than the present study's exercise-parings.

Additionally, the validity of the HDT device as a measure of PF is a possible limitation of the present study. Throughout the literature, a diverse range of devices have been utilised to assess PF, including pressure transducers immersed in water-filled punch bags (Fortin, Lamontagne & Gadouas, 1995), measurement devices within dummies (Walilko, Viano & Bir, 2005) and piezoelectric-force sensors placed within targets (Atha et al., Girodet et al., 1985; Smith et al., 2000). As only the present study and Topal et al., (2011) have examined punching/striking force using a HDT, future research should attempt to further verify the HDT devices reliability and validity as an accurate measure of PF.

It is recommended that future research examines PAP effects of different CT exercise-pairings on PF. Stojsih, Boitano, Wilhelm and Bir (2010) judged that axial loaded lower-body exercises (e.g. back squat) optimised punching force, as vertical ground reaction forces (GRF) are the main contributor to PF (Akutagawa & Kojima, 2005). However, Cesari and Bertucco (2008) supposed horizontal GRF was the principal element. Consequently, future CT research should examine the relationship between vertical (e.g. deadlift) and horizontal (e.g. sled pulls/pushes) GRF exercises to determine which force plane optimises PF to the greatest degree.

In conclusion, the ability to repeatedly perform forceful punches is essential in amateur boxing as the single most successful strategy is to land high percentages of straight punches (Blower, 2007). The present study demonstrated that CT was marginally superior to MST in augmenting straight PF and 1-RM strength in the upper- and lower-body. As a strong correlation exists between strength, power and punching force in combat athletes (Irineu, Guilherme-Giannini, Ronaldo, Saulo & Emerson, 2013), it is paramount to develop strength and power capabilities to optimally prepare boxers for competition (Lenetsky et al., 2013). Consequently, amateur boxers should consider performing CT within a periodised training programme (see Appendix P) as the main components of jab and rear-hand cross PF (elbow extension and rear-leg drive, respectively) can be optimally augmented (Tack, 2013). Therefore, the implementation of a CT programme into an amateur boxing training regimen appears to augment straight PF, and subsequently, competitive performance.

5500 words

References

Adams, K, O'Shea, J. P., O'Shea, K. L. & Climstein, M. (1992). The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *Journal of Applied Sport Science Research*, 6, 36-41.

Akutagawa, S. & Kojima, T. (2005). Trunk rotation torques through the hip joints during the one- and two-handed backhand tennis strokes. Journal of Sport Science, 23, 781–793.

Alter, M.J. (1998). *Sport stretching*, (2nd Edition), Champaign, IL: Human Kinetics.

Altman, D.G. (1991). *Practical statistics for medical research,* Boca Raton, FL: CRC Press.

Arabatzi, F., Kellis, E. & Sáez de Villarreal, E. (2010). Vertical jump biomechanics after plyometric, weight lifting, and combined (weight lifting and plyometric) training. *Journal of Strength and Conditioning Research*, 24(9), 2440-2448.

Atha, J., Yeadon, M.R., Sandover, J. & Parsons, K.C. (1985). The damaging punch. British Medical Journal, 291, 1756–1757.

Atkinson, G. & Neville, A.M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine*, 26(4), 217-238.

Austin, D. & Mann, B. (2012). *Powerlifting*, Champaign, IL: Human Kinetics.

Baechle, T., & Earle, R. (2008). *Essentials of strength training and conditioning,* (3rd Edition), Champaign, IL: Human Kinetics.

Baker, D. (2003). Acute effects of enhancing heavy and light resistances on power output during upper-body complex power training. *Journal of Strength and Conditioning Research*, 17, 493-497.

Barker, R.J. & Schofield, M.R. (2008). Inference about magnitude of effects. *International Journal of Sports Physiology and Performance*, 3(4), 547-557.

Batterham, A.M. & Hopkins, W.G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, 1, 50-57.

Bird, S.P., Tarpenning, K.M. & Marino, F.E. (2005). Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Medicine*, 35(10).

Blower, G. (2007). *Boxing Training, Skills and Techniques*. Marlborough, UK: Crowood Press Ltd.

Bompa, T. (1999). *Periodization: theory and methodology of training*, (4th Edition), Champaign, IL: Human Kinetics.

Bompa, T. & Carrera, M. (2005). *Periodization training for sports*, (2nd Edition), Champaign, IL: Human Kinetics.

Bompa, T. & Haff, G. (2009). *Periodization: theory and methodology of training*, (5th Edition), Champaign, IL: Human Kinetics.

Bompa, T., Di Pasquale, M. & Cornacchia, L. (2003). *Serious strength training*, (3rd Edition), Champaign, IL: Human Kinetics.

Bosco, C., Cardinale, M. & Tsarpela, O. (1999). Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. *European Journal of Applied Physiology and Occupational Physiology*, 79(4), 306-311.

Boyle, M. (2004). *Functional training for sports*, Champaign, IL: Human Kinetics.

Boyle, M. (2010). *Advances in functional training*, Aptos, CA: On Target Publications.

Brandenburg, J.P. (2005). The acute effects of prior dynamic resistance exercise using different loads on subsequent upper-body explosive performance in resistance-trained men. *Journal of Strength and Conditioning Research*, 19, 427-432.

Brewer, C. (2008). *Strength and conditioning for sport: a practical guide for coaches*, Headingly, Leeds: Sports Coach UK.

Broker, J.P. & Crawley, J.D. (2002). Advanced sport technologies: enhancing Olympic performance. *In Biomechanics XIX* (edited by Blackwell, J.R.), 323-327. University of San Francisco.

Cardinale, M., Newton, R. & Nosaka, K. (2011). *Strength and conditioning: biological principles and practical applications*, Chichester, WS: Wiley-Blackwell.

Cassidy, T.G, Jones, R.L. & Potrac, P. (2009). *Understanding sports coaching: the social, cultural and pedagogical foundations of coaching practice*, Taylor & Francis.

Cesari, P. & Bertucco, M. (2008). Coupling between punch efficacy and body stability for elite karate. *Journal of Science and Medicine in Sport*, 11, 353–356.

Cheraghi, M., Alinejad, H.A., Arshi, A.R. & Shirzad, E. (2014). Kinematics of Straight Right Punch in Boxing. *Annals of Applied Sport Science*, 2(2), 39-50.

Chiu, L.Z. & Barnes, J. (2003). The fitness fatigue model revisited: implications for short- and long-term training. *Strength and Conditioning Journal,* 25, 42-51.

Chu, D.A. (1996). *Explosive power and strength: complex training for maximum results*, Champaign, IL: Human Kinetics.

Comyns, T.M., Harrison, A.J., Hennessy, L. & Jensen, R.L. (2006). The optimal contrast training rest interval for athletes from anaerobic sports. *Journal of Strength and Conditioning Research*, 20, 471-476.

Comyns, T.M., Harrison, A.J., Hennessy, L. & Jensen, R.L. (2007). Identifying the optimal resistive load for complex training in male rugby players. *Sports Biomechanics*, 6, 59-70.

Cordes, K. (1991). Boxing: Reasons to strength train for amateur boxing. *Journal of Strength and Conditioning*, 13(5), 18-21.

Cormie, P., McCaulley, G.O. & McBride, J.M. (2007). Power versus strength–power jump squat training: influence on the load–power relationship. *Medicine and Science in Sports and Exercise*, 39(6), 996–1003.

Cormie, P., McGuigan, M.R. & Newton, R.U. (2011). Developing maximal neuromuscular power: part 1 – biological basis of maximal power production. *Journal of Sports Medicine,* 41(1), 17-38.

Cormie, P., McGuigan, M.R. & Newton, R.U. (2011). Developing maximal neuromuscular power: part 2 – training considerations for improving maximal power production. *Journal of Sports Medicine,* 41(2), 125–146.

Cressey, E. & Fitzgerald, M. (2008). *Maximum strength,* Philadelphia, PA: Da Capo Press.

Crewther, B.T., Kilduff, L.P., Cook, C.J., Middleton, M.K., Bunce, P.J. & Yang, G.Z. (2011). The acute potentiating effects of back squats on athlete performance. *Journal of Strength and Conditioning Research*, 25, 3319-3325.

Davis, P., Leithauser, R.M. & Beneke, R. (2014). The energetics of semi-contact 3 x 2-min amateur boxing. *International Journal of Sports Physiology and Performance*, 9(9), 233-239.

Davis, P., Wittekind, A. & Beneke, R. (2013). Amateur boxing: activity profile of winners and losers. *International Journal of Sports Physiology and Performance*, 8(6), 599.

Dengel, D.R., George, T.W., Bainbridge, C., Fleck, S.J., Van Handel, P.J. & Kearney, J.T. (1987). Training responses in national team boxers. *Medicine and Science in Sports and Exercise*, 19, 277.

Dohoney, P., Chromiak, J.A., Lemire, D., Abadie, B.R. & Kovacs, C. (2002). Prediction of one repetition maximum (1-RM) strength from a 4-6 RM and 7-10 RM submaximal strength test in healthy young adult males. *Journal of Exercise Physiology,* 5(3), 54-59.

Duthie, G.M., Young, W.B. & Aitken, D.A. (2002). The acute effects of heavy loads on jump squat performance: an evaluation of the complex and contrast methods of power development. *Journal of Strength and Conditioning Research*, 16, 530-538.

Dyson, R., Smith, M., Martin, C. & Fenn, L. (2007). Muscular recruitment during rear hand punches delivered at maximal force and speed by amateur boxers. *International Symposium on Biomechanics in Sport*, 25.

Ebben, W.P. (2002). Complex training: a brief review. *Journal of Sports Science and Medicine*, 1, 42-46.

Ebben, W.P & Blackhard, D.O. (1997). Developing a strength-power programme for amateur boxing. *National Strength and Conditioning Journal*, 19(1), 42-51.

Ebben, W.P., Jenson, R.L. & Blackhard, D.O. (2000). Electromyographic and kinetic analysis of complex training variables. *Journal of Strength and Conditioning Research,* 14, 451-456.

Elliott, B.C., Wilson, G.J.. & Kerr, G.K. (1989). A biomechanical analysis of the sticking region in the bench press. *Medicine and Science in Sports and Exercise*, 21, 450-462.

Esformes, J.I., Cameron, N. & Bampouras, T.M. (2010). Post-activation potentiation following different modes of exercise. *Journal of Strength and Conditioning Research*, 24, 1911-1916.

Evans, A., Hodgkins, T., Durham, M., Berning, J. & Adams, K. (2000). The acute effects of 5RM bench press on power output. *Medicine and Science in Sport and Exercise*, 32, 311.

Farup, J. & Sorensen, H. (2010). Postactivation potentiation; upper body force development changes after maximal force intervention. *Journal of Strength and Conditioning Research*, 24, 1874-1879.

Fatouros, I.G., Jamurtas, A.Z. & Leontsini, D. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. *Journal of Strength and Conditioning Research*, 14(4), 470–476.

Faul, F., Erdfelder, E., Buchner, A. & Lang, A.G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behavior Research Methods*, 41, 1149-1160.

Filimonov, V.I., Koptsev, K.N., Husyanov, Z.M. & Nazarov, S.S. (1985). Boxing: Means of increasing strength of punch. *National Strength and Conditioning Journal*, 7(6), 65-66.

Fleck, S.J. & Kearney, J.T. (1993). *Physical conditioning for amateur boxing*, in B.D. Jordan (Eds.) Medical Aspects of Boxing, Boca Raton, FL: CRC Press.

Folland, J.P. & Williams, A.G. (2007). The adaptations to strength training: morphological and neurological contributions to increased strength. *Journal of Sports Medicine*, 37, 145-168.

Fortin, Y., Lamontagne, M. & Gadouas, A. (1995). Punching bag dynamometer. Journal of Biomechanics, 27, 758–759.

Gabriel, D.A., Kamen, G. & Frost, G. (2006). Neural adaptations to resistive exercise: mechanisms and recommendations for training practices. *Sports Medicine*, 36(2), 133-149.

Gambetta, V. (2007). *Athletic Development: The art and science of functional sports conditioning,* Champaign, IL: Human Kinetics.

Gastin, P.B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports Medicine*, 31(10), 725-741.

Gilbert, G. & Lees, A. (2005). Changes in the force development characteristics of muscle following repeated maximum force and power exercise. *Ergonomics,* 48, 1576-1584.

Girodet, P., Vaslin, P., Dabonneville, M. & Lacouture, P. (2005). Two-dimensional kinematic and dynamic analysis of a karate straight punch. *Computer Methods in Biomechanics and Biomedical Engineering*, 8, 117–118.

Gouvêaa, A.L., Fernandesa, I.A., Césara, E.P., Silvaa, W.A.G. & Gomesa, P.S.C. (2013). The effects of rest intervals on jumping performance: A meta-analysis on post-activation potentiation studies. *Journal of Sports Sciences*, 31(5), 459-467.

Guidetti, L., Musulin, A. & Baldari, C. (2002). Physiological factors in middleweight boxing performance. *Journal of Sports Medicine and Physical Fitness*, 42, 309-314.

Gullett, J., Tillman, M., Gutierrez, G. & Chow, J. (2009). A biomechanical analysis of back and front squats in healthy trained individuals. *Journal of Strength and Conditioning Research*, 23(1), 284-292.

Gullich, A. & Schmidtbleicher, D. (1996). MVC induces short term potentiation of explosive force. *New Studies in Athletics*, 11, 67-81.

Haff, G.G., Whitley, A. & Potteiger, J.A. (2001). A brief review: explosive exercises and sports performance. *Strength and Conditioning Journal*, 23(3), 13.

Harris, G.R., Stone, M.H., O'Bryant, H., Proulx, C.M. & Johnson, R.L. (2000). Short-Term Performance Effects of High Power, High Force, or Combined Weight-Training Methods. *Journal of Strength & Conditioning Research*, 14(1).

Hickey, K. (1980). *Boxing: The Amateur Boxing Association Coaching Manual*. London: Kaye & Ward.

Hickson, R.C., Hidaka, K. & Foster, C. (1994). Skeletal muscle fibre type, resistance training, and strength-related performance. *Medicine and Science in Sports and Exercise,* 26, 593-598.

Hopkins, W.G. (2006). Spreadsheets for analysis of controlled trials, with adjustment for a subject characteristic. *Sportscience*, 10, 46–50.

Horwath, R. & Kravitz, L. (2008). Postactivation potentiation: a brief review. *IDEA Fitness Journal*, 1(1).

Howe, L., Goodwin, J. & Blagrove, R. (2014). The integration of unilateral strength training for the lower extremity within an athletic performance programme. *Professional Strength and Conditioning Journal*, 33, 19-24.

Howell, D.C. (1997). *Statistical methods for psychology*. Belmont: Duxbury.

Hrysomallis, C. & Kidgell, D. (2001). Effect of heavy dynamic resistive exercise on acute upper-body power. *Journal of Strength and Conditioning Research,* 15, 426-430.

Irineu, L., Guilherme-Giannini, A., Ronaldo, K., Saulo, G. & Emerson, F. (2013). Predicting punching acceleration from selected strength and power variables in elite karate athletes: a multiple regression analysis. *Journal of Strength and Conditioning Research*, 1(1).

Jamieson, J. (2009). *Ultimate MMA conditioning*, Cincinnati, OH: Performance Sport Inc.

Jensen, R.L. & Ebben, W.P. (2003). Kinetic analysis of complex training rest interval effect on vertical jump performance. *Journal of Strength and Conditioning Research,* 17, 345-349.

Jones, P., Bampouras, T. & Comfort, P. (2013). A review of complex and contrast training: implications for current practice. *Professional Strength and Conditioning*, 29 (1), 11-20.

Jones, P. & Lees, A. (2003). A biomechanical analysis of the acute effects of complex training using lower limb exercises. *Journal of Strength and Conditioning Research,* 17, 694-700.

Jordan, B. D. (1993). *Medical aspects of boxing*, Boca Raton, FL: CRC Press.

Karpilowski, B.M., Nosarzewski, Z. & Staniak, Z. (1994). A versatile boxing simulator. *Biology of Sport*, 11, 133-139.

Kilduff, L.P., Bevan, H.R., Kingsley, M.I., Owen, N., Bennett, M.A., Bunce, P.J., Hore, A.M., Maw, J.R. & Cunningham, D.J. (2007). Postactivation potentiation in professional rugby players; optimal recovery. *Journal of Strength and Conditioning Research,* 21, 1134-1138.

Kilduff, L.P., Owen, N., Bevan, H.R., Bennett, M.A., Kingsley, M.I. & Cunningham, D.J. (2008). Influence of recovery time on post-activation potentiation in professional rugby players. *Journal of Sports Science,* 26, 795-802.

Kim, E., Dear, A., Ferguson, S. L., Seo, D. & Bemben, M. G. (2011). Effects of 4 weeks of traditional resistance training vs. superslow strength training on early phase adaptations in strength, flexibility and aerobic capacity. *Journal of Strength and Conditioning Research*, 25(11), 3006–3013.

Kirkwood, B. & Sterne, J. (2003). *Essential medical statistics,* (2nd Edition), Malden, MA: Wiley-Blackwell.

Komi, P.V. (2003). *Strength and power in sport,* Oxford: Blackwell Science.

Kraemer, W.J. & Ratamess, N.A. (2004). Fundamentals of resistance training: progression and exercise prescription. *Medicine and Science in Sports and Exercise*, 36(4), 674–88.

Kritz, M.F. & Croin, J. (2008). Static posture assessment screen of athletes: benefits and considerations. *Strength and Conditioning Journal*, 30(5), 18-27.

Kubo, K., Kanehisa, H. & Fukunaga T. (2001). Effects of isometric training on the elasticity of human tendon structures in vivo. *Journal of Applied Physiology,* 91(1), 26–32.

La Bounty, P. Campbell, B.I., Galvan, E., Cooke, M. & Antonio, J. (2011). Strength and conditioning considerations for mixed martial arts. *Strength and Conditioning Journal,* 33(1), 56-67.

Lasnier, D. (2012). Timed sets for speed strength. *Davidlasnier.com.* Retrieved October 21, 2013, from http://davidlasnier.com/2012/timed-sets-for-speed-strength.

Lenetsky, S., Harris, N. & Brughelli, M. (2013). Assessment and contributors of punching forces in combat sports athletes: implications for strength and conditioning. *Strength and Conditioning Journal*, 35(2), 1-7.

Liossis, L.D., Forsyth, J., Liossis, C. & Tsolakis, C. (2013). The acute effect of upper-body complex training on power output of martial art athletes as measured by the bench press throw exercise. *Journal of Human Kinetics*, 39, 167-175.

Lockwood, C.M. & Tant, C.L. (1997). Mechanical and electromyographical analysis of a boxer's jab. *International Symposium on Biomechanics in Sport*, 15, 269-275.

MacDonald, C.J., Lamont, H.S. & Garner, J.C. (2012). A comparison of the effects of six weeks of traditional resistance training, plyometric training, and complex training on measures of strength and anthropometrics. *Journal of Strength and Conditioning Research*, 26(2), 422–431.

Mangine, G.T., Ratamess, N.A., Hoffman, J.R., Faigenbaum, A.D., Kang, J. & Chilakos, A. (2008). The effects of combined ballistic and heavy resistance training on maximal lower- and upper-body strength in recreationally trained men. Journal of Strength and Conditioning Research, 22(1), 132-139.

Mangus, B.C., Takahashi, M., Mercer, J.A., Holcomb, W.R., McWhorter, J.W. & Sanchez, R. (2006). Investigation of vertical jump performance after completing heavy squat exercises. *Journal of Strength and Conditioning Research*, 20, 597-600.

Markovic, G.I., Jukic, D. & Milanovic, D. (2007). Effects of sprint and plyometric training on muscle function and athletic performance. *Journal of Strength and Conditioning Research*, 21(2), 543–549.

Matthews, M. & Comfort, P (2008). Applying complex training principles to boxing: a practical approach, *Strength and Conditioning Journal,* 30(5), 12-15.

Matthews, M., O'Conchuir, C. & Comfort, P. (2009). The acute effects of heavy and light resistances on the flight time of a basketball push-pass during upper-body complex training. *Journal of Strength and Conditioning Research,* 23, 1988-1995.

McArdle, W.D., Katch, F.I. & Katch, V.L. (2000) *Essentials of exercise physiology*, (2^{nd} Edition), Baltimore, MA: Lippincott, Williams & Wilkins.

McBride, J.M., Triplett-McBride, T., Davie, A. & Newton, R.U. (2002). The effect of heavy vs. light-load jump squats on the development of strength, power, and speed. *Journal of Strength and Conditioning Research,* 16, 75-82.

McCann, M.R. & Flannagan, S.P. (2010). The effects of exercise selection and rest interval on post-activation potentiation of vertical jump performance. *Journal of Strength and Conditioning Research,* 24, 1285-1291.

MacDonald, C.J., Lamont, H.S. & Garner, J.C. (2012). A comparison of the effects of six weeks of traditional resistance training, plyometric training, and complex training on measures of strength and anthropometrics. *Journal of Strength and Conditioning Research*, 26(2), 422–431.

McMillian, D. J., Moore, J. H., Hatler, B. S. & Taylor, D. C. (2006). Dynamic vs. static-stretching warm up: the effect on power and agility performance. *Journal of Strength and Conditioning Research*, 20(3), 492-499.

Newton, H. (2010). *Explosive lifting for sports,* Champaign, IL: Human Kinetics.

Obmiński, Z., Borkowski, L. & Sikorski, W. (2011). The shot put performance as a marker of explosive strength in polish amateur boxers. *Archives of Budo*, 7(3), 173-177.

Olsen, P.D. & Hopkins, W.G. (2003). The effect of attempted ballistic training on the force and speed of movements. *Journal of Strength and Conditioning Research*, 17(2).

Partridge, K., Hayes, J.P., James, D.A., Hill, C., Gin, G., & Hahn, A. (2005). A wireless-sensor scoring and training system for combative sports. *Smart Structures, Devices, and Systems II*, 5649, 402–408.

Peterson, M.D., Rhea, M.R. & Alvar, B.A. (2004). Maximizing strength development in athletes: a meta-analysis to determine the dose-response relationship. *Journal of Strength and Conditioning Research,* 18(2), 377-382.

Pierce, J., Reinbold, K., Lyngard, B., Goldman, R. & Pastore, C. (2006). Direct measurement of punch force during six professional boxing matches. *Journal of Quantitative Analysis in Sports,* 2.

Piorkowski, B.A., Lees, A. & Barton, G.J. (2011). Single maximal versus combination punch kinematics. *Sports Biomechanics*, 10(1), 1-11.

Price, R. (2006). *The Ultimate Guide to Weight Training For Boxing*, (2nd Edition), Chicago, IL: Price World Publishing.

Rahmi, R. & Behpur, N. (2005). The effect of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength. *Physical Education and Sport*, 3(1), 81-91.

Rajamohan, G., Kanagasabai, P., Krishnaswamy, S. & Balakrishnan, A. (2010). Effect of complex and contrast resistance and plyometric training on selected strength and power parameters. *Journal of Experimental Sciences*, 1(12), 1-12.

Reynolds, J.M., Gordon, T.J. & Robergs, R.A. (2006). Prediction of one repetition maximum strength from multiple repetition maximum testing and anthropometry. *Journal of Strength and Conditioning Research*, 20(3), 584-592.

Rippetoe, M. & Kilgore, L. (2009). *Practical programming for strength training*, Wichita Falls, TX: The Aasgaard Company.

Sáez de Villarreal, E.S., Requena, B., Izquierdo, M., & Gonzalez-Badillo, J. J. (2013). Enhancing sprint and strength performance: Combined versus maximal power, traditional heavy-resistance and plyometric training. *Journal of Science and Medicine in Sport*, 16(2), 146.

Sandler, D. (2005). *Developing explosive acceleration,* Champaign, IL: Human Kinetics.

Schwanbeck, S., Chilibeck, P.D. & Binsted, G. (2009). A comparison of free weight squat to smith machine squat using electromyography. *Journal of Strength and Conditioning Research*, 23(9), 2588-2591.

Scott, S.L. & Docherty, D. (2004). Acute effects of heavy pre-loading on vertical and horizontal jump performance. *Journal of Strength and Conditioning Research,* 18, 201-205.

Shoepe, T.C., Ramirez, D.A., Rovetti, R.J., Kohler, D.R. & Almsted, H.C. (2011). The effects of 24 weeks of resistance training with simultaneous elastic and free weight loading on muscular performance of novice lifters. *Journal of Human Kinetics*, 93-106.

Siff, M., C. (2000). *Supertraining*, (5th edition), Denver: Supertraining Institute.

Smith, M.S. (2006). Physiological profile of senior and junior England international amateur boxers. *Journal of Sports Science and Medicine*, 5, 74-89.

Smith, M.S., Dyson, R.J., Hale, T. & Janaway, L. (2000). Development of a boxing dynamometer and its punch force discrimination efficacy. *Journal of Sports Sciences*, 18(6), 445-450.

Solovey, B.A. (1983). Exercises with weights as a means of improving hitting speed in young boxers. *Soviet Sports Review*, 18(2), 100-102.

Spaniol, F. J. (2012). Striking skills: developing power to turn. *Strength & Conditioning Journal*, 34, 57–60.

Stojsih, S., Boitano, M., Wilhelm, M. & Bir, C. (2010). A prospective study of punch biomechanics and cognitive function for amateur boxers. *British Journal of Sports Medicine*, 44(10), 725-730.

Stone, M.H., O'Bryant, H.S., McCoy, L., Coglianese, R., Lehmkuhl, M. & Schilling, B. (2003). Power and maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research*, 17, 140–147.

Stone, M.H., Stone, M. & Sands, W.A. (2007). *Principles and practice of resistance training*, Champaign, IL: Human Kinetics.

Storen, O., Helgerud, J., Stoa, E.M. & Hoff, J. (2008). Maximal strength training improves running economy in distance runners. *Medicine and Science in Sports and Exercise*, 40(6), 1089–1094.

Tack, C. (2013). Evidence-based guidelines for strength and conditioning in mixed martial arts. *Strength and Conditioning Journal*, 35(5), 79-92.

Talpey, S.W., Young, W.B. & Saunders, N. (2014). The acute effects of conventional, complex, and contrast protocols on lower-body power. *Journal of Strength and Conditioning Research*, 28(2), 361–366.

Terzis G, Georgiadis G, Vassiliadou E, Manta P. (2003). Relationship between shot put performance and triceps brachii fibre type composition and power production. *European Journal of Applied Physiology*, 90, 10–15.

Thomson, E., Lamb, K.L. & Nicholas, C. (2013). The development of a reliable amateur boxing performance analysis template. *Journal of Sports Sciences, 31*, 516-528.

Topal, V., Ramazanoglu, N., Yilmaz, S., Camliguney, A.F. & Kaya, F. (2011). The effect of resistance training with elastic bands on strike force at taekwondo. *American International Journal of Contemporary Research*, 1(2), 140-144.

Turner, A.N. (2009). Training for power: principles and practice. *Professional Strength and Conditioning*, 14, 20-32.

Turner, A.N., Baker, E.D. & Miller, S.C. (2011). Increasing the impact force of the rear hand punch. *National Strength and Conditioning Journal*, 33(6), 2-9.

Umeda, A. & Ueda, K. (1990). Study on the dynamic force/acceleration measurements. *Proceedings of the 5th International Conference on Solid-State Sensors and Actuators and Eurosensors III*, 21(1), 285-288.

Vaile, J.M., Gill, N.D. & Blazevich, A.J. (2007). The effect of contrast water therapy on symptoms of delayed onset muscle soreness. *Journal of Strength and Conditioning Research*, 21(3), 697-702.

Verkhoshansky, Y. & Verkhoshansky, N. (2011). *Special strength training manual for coaches,* Rome, IT: Verkhoshansky SSTM.

Walilko, T.J., Viano, D.C. & Bir, C.A. (2005). Biomechanics of the head for Olympic boxer punches to the face. *British Journal of Sports Medicine*, 39(7), 710-719.

Walker, S., Ahtiainen, J.P. & Hakkinen, K. (2010). Acute neuromuscular and hormonal responses during contrast loading: effect of 11 weeks of contrast training. *Scandinavian Journal of Medicine and Science in Sport*, 20, 226-234.

Wallace, M.B. & Flanagan, S. (1999). Boxing: resistance training considerations for modifying injury risk*. National Strength and Conditioning Journal*, 21(3), 31-39.

Weber, K.R., Brown, L.E., Coburn, J.W. & Zinder, S.M. (2008). Acute effects of heavy-load squats on consecutive squat jump performance. *Journal of Strength and Conditioning Research,* 22, 726-730.

Weimann, T. (2000). *Warrior speed*, Wethersfield, CT: Turtle Press.

Wilson, G.J., Newton, R.U., Murphy, A.J. & Humphries, B.J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sports Exercise,* 25, 1279-1286.

Wong, E. (2010). Strength and power training for MMA athletes. *Ultimate MMA Strength and Conditioning,* Ontario: CN.

Young, W.B., Jenner, A. & Griffiths, K. (1998). Acute enhancement of power performance from heavy-load squats. *Journal of Strength and Conditioning Research,* 12, 82-84.

Zatsiorsky, V.M. & Kraemer, W.J. (2006). *Science and practice of strength training*, (2nd Edition), Champaign, IL: Human Kinetics.

Zhao, F.Q. & Craig, R. (2003). Ca2+ causes release of myosin heads from thick filament surface on the millisecond time scale. *Journal of Molecular Biology*, 327, 145-158.

Appendices

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Appendix A: Contrast Training Research.

Table 1. Contrast Training Research (Jones, Bampouras & Comfort, 2013).

Author(s)	Subjects	Protocol	Measures	Results
Baker (2003)	16 rugby league players – divided into E & C groups	C session: 2x5 BPT with 50kg load (3 min rest). E session: 6 reps at 65% 1-RM BPRESS between BPT sets	BPT (PPO) using 50kg load	4.5%^ PPO post intervention (E group)
Comyns, Harrison, Hennessy & Jensen (2006)	18 subjects (sprinters, jumpers & rugby players)	1 x 5-RM BSQT	CMJ flight time (performed before, 30 sec, 2, 4 & 6 min post)	*S*^ flight time 4 & 6 min post
Comyns, Harrison, Hennessy & Jensen (2007)	12 professional rugby league players	3 BSQT at 65, 80 & 93% 1-RM	DJ flight time (before & immediately post)	S^{v} GCT in all conditions
Crewther, Kilduff, Cook, Middleton, Bunce & Yang (2011)	9 sub-elite male rugby players	3-RM BSQT	CMJ (height) 4, 8, 12 & 16 min post	*S*^ CMJ flight time 4, 8 & 12 min post
Evans, Hodgkins, Durham, Berning & Adams (2000)	10 college athletes	1 x 5-RM BPRESS	2-handed SMBT, pre and 4 min post	31.4cm^ in MB distance tossed
Esformes, Cameron & Bampouras (2010)	13 college athletes	1 x 3-RM BSQT vs 24 plyometric contacts	CMJ (height), 5 min post	CMJ *S*^ after BSQT compared with plyometrics
Kilduff, Bevan, Kingsley, Owen, Bennett, Bunce, Hore, Maw & Cunningham (2007)	23 professional rugby players	3-RM BPRESS	1 x BPT (PPO) before, 4, 8, 12, 16 & 20 min post	*S*^ PPO 4, 8, 12 & 16 min post
Kilduff, Owen, Bevan, Bennett, Kingsley & Cunningham (2008)	23 professional rugby players	3-RM BSQT	CMJ (PPO) before, 4, 8, 12, 16 & 20 min post	*S*^ PPO 4, 8 &12 min post
Matthews, O'Conchuir & Comfort (2009)	12 male athletes	5 x 85% 1-RM BPRESS vs. 2.3kg MBCP	Basketball chest pass (flight time)	*S*^ flight time post MBCP, *S*^ flight time post BPRESS

McCann & Flannagan (2010)	14 NCAA division 1 volleyball players	5-RM BSQT vs. 5-RM HC	CMJ (height) 4 & 8 min post	*S*^ in CMJ, 4 min post BSQT. *NS* difference post HC
Scott & Doherty (2004)	19 male athletes	1 x 5-RM BSQT	CMJ (height) & SLJ (distance) pre & 5 min post	20%^ in CMJ, 23%^ in SLJ post
Walker, Ahtiainen & Hakkinen (2010)	10 recreational male resistance trainees	3 x 80% 1-RM BSQT	SQJ (height) 3 min post	*S*^ in SQJ height
Weber, Brown, Coburn & Zinder (2008)	12 NCAA division 1 male athletes	5 BSQT at 85% 1-RM vs. 5 SQJ	SQJ (height) pre & 3 min post	*S*^ in SQJ height 3 min post BSQT, *NS* difference in SQJ height 3 min post 5 SQJ
Young, Jenner & Griffiths (1998)	10 males	1 x 5-RM BSQT	LCMJ (height) pre & 4 min post	2.8%^ in LCMJ height

Key

Exercises: BSQT = back squat, BPRESS = bench press, BPT = bench press throw, MBPD = medicine ball power drops, MBCP = medicine ball chest pass, SMBT = seated medicine ball toss, LCMJ = loaded countermovement jump, SQJ = squat jump, HS = half squats, QS = quarter squats, CMJ = countermovement jump, DJ = drop jump, SLJ = standing long jump, HC = hang clean, RM = repetition maximum.

Groups: E = experimental, C = control.

Measures: GRF = ground reaction force, GCT = ground contact time, PPO = peak power output, APO = average power output, RSI = reactive strength index.

Results: *S* = significant, *NS* = non-significant, ^ = increase, v = decrease.

Appendix B: Participant Information Sheet.

University of Chester

Title of Project: The effects of 4 weeks of contrast training versus maximal strength training on punch force in 20-30 year old male amateur boxers.

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

The purpose of the study is to obtain sufficient evidence to demonstrate the performance effects of 4 weeks of contrast training versus maximal strength training on punch force in 20-30 year old male amateur boxers.

Why have I been chosen?

You have been chosen because you are an amateur boxer between 20-30 years of age who currently completes boxing specific training twice per week, has 2 years or more of boxing experience and are classed as a novice resistance exercise trainee (less than 12 months experience).

Do I have to take part?

It is up to you to decide whether or not to take part within the study. If you decide to take part you, will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your rights in any way and will not be questioned.

What will happen to me if I take part?

If you decide to take part, you will be given this information sheet to keep and asked to sign the consent form. You will be tested for your one-repetition maximum score on 2 strength exercises (back squat, bench press) at the initial phase of the research. You will also be tested for maximal punching force via a Herman Digital Trainer (HDT) sensor attached to a 25 kilogram punch bag. You will be required to perform 2 contrast training or maximal strength training sessions per week for 4 weeks and then be re-tested on the 2 one-repetition maximum and punch force tests at the research's conclusion. The 1-RM tests for both the back squat and bench press will both be completed within 60 minutes; however each subject's 1-RM tests will vary in duration depending upon how quickly a 1-RM score is reached in both exercises. Each of the twice-weekly training sessions completed by both CT and MST subjects will last approximately 70 minutes, including warm-up, mobility and cool down procedures. No one will be identifiable in the final report and all results will be kept confidential by the lead researcher.

What are the possible disadvantages and risks of taking part?

- Slight risk of injury (due to maximal weights being used).
- Possible delayed onset muscular soreness (DOMS) due to new training stimulus.
- Increased number of weekly training hours (if you continue with your current training regimen).
- Possible increase in nutritional requirements due to increased training load.

What are the possible benefits of taking part?

- Learn new exercises and techniques that can be used long after the research has been completed.
- Possible performance improvements (punching force).
- Enhanced one-repetition maximum scores on strength tests.
- Possible enhanced punching force/power.
- Stronger muscles, tendons and ligaments (due to resistance training).
- Greater injury resistance.
- Increased levels of resistance training experience.

What if something goes wrong?

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Life Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research and the researcher's university supervisor will have access to such information. Once the research had concluded, all research results and data will be kept confidential and secured on a USB pen stick, of which will be placed within a secure location for a minimum of 10 years.

What will happen to the results of the research study?

The results will be written up into a research project for my final project of my MSc degree in Sport Science (Strength and Conditioning pathway). Individuals who participate will not be identified in any subsequent report or publication and all data will be kept completely confidential.

Who is organising the research?

The research is conducted as part of an MSc in Strength and Conditioning within the Department of Sport & Exercise Sciences at the University of Chester. The study is organised with supervision from the department, by Edward Stanley, an MSc student.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Edward Stanley – @chester.ac.uk

Thank you for your interest in this research.

Appendix C: Participant Consent Form.

University of Chester

Title of Project: The effects of 4 weeks of contrast training versus maximal strength training on punch force in 20-30 year old male amateur boxers.

Name of Researcher: Edward Stanley

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

3. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Researcher	Date	Signature

Appendix D: Physical Activity Readiness Questionnaire (PAR-Q).

Title of Project: The effects of 4 weeks of contrast training versus maximal strength training on punch force in 20-30 year old male amateur boxers.

Name of Researcher: Edward Stanley

Please circle the appropriate response:

1. Has your doctor ever said that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise? **Yes/No**
2. Do you have high blood pressure? **Yes/No**
3. Do you have Diabetes Mellitus or any other metabolic disease? **Yes/No**
4. Has your doctor ever said that you have raised cholesterol? **Yes/No**
5. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by your doctor? **Yes/No**
6. Have you ever felt pain in your chest when you do physical exercise? **Yes/No**
7. Is your doctor currently prescribing you drugs or medication? **Yes/No**
8. Have you ever suffered from unusual shortness of breath at rest or with mild exertion? **Yes/No**
9. Is there any history of Coronary Heart Disease in your family? **Yes/No**
10. Do you often feel faint, have spells of severe dizziness or have lost consciousness? **Yes/No**
11. Do you currently drink more than the average amount of alcohol per week (21 units for men and 14 units for women)? **Yes/No**
12. Do you currently smoke? **Yes/No**
13. Do you work in a job that is physically demanding? **Yes/No**
14. Are you, or is there any possibility that you might be pregnant? **Yes/No**
15. Do you know of any other reason why you should not participate in a programme of physical activity? **Yes/No**

If YES please give details:

____

If you answered: - **YES to one or more questions:**

If you have not recently done so, consult with your doctor by telephone or in person before increasing your physical activity and/or taking a fitness appraisal. Tell your doctor what questions you answered yes to on PAR-Q or present your PAR-Q copy. After medical evaluation, seek advice from your doctor as to your suitability for:

1) Unrestricted physical activity starting off easily and progressing gradually

2) Restricted or supervised activity to meet your specific needs, at least on an initial basis.

NO to all questions:

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

1) A physical research study

Assumption of Risk

I hereby state that I have read, understood and answered honestly the questions above. I also state that I wish to participate in activities, which may include aerobic exercise, resistance exercise and stretching. I realise that my participation in these activities involves the risk of injury and even the possibility of death. Furthermore, I hereby confirm that I am voluntarily engaging in an acceptable level of exercise, which has been recommended to me.

Participant Name:	
Participant Signature:	

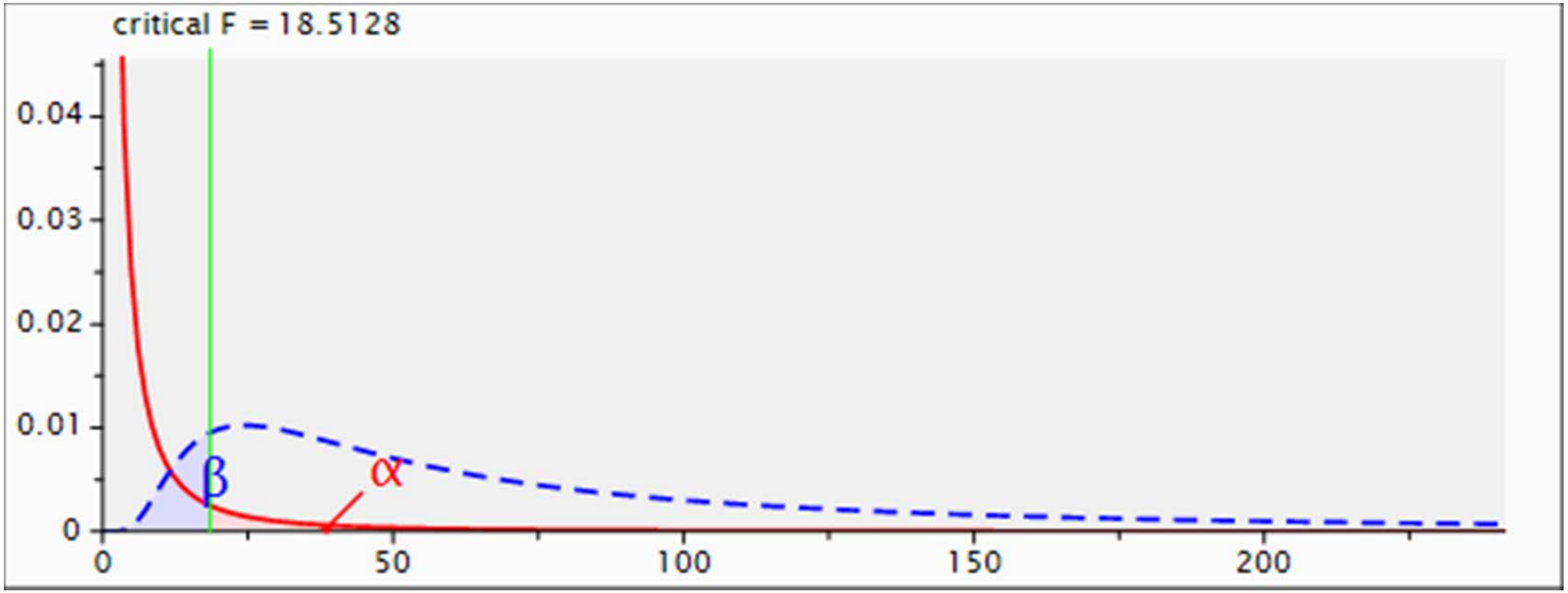
Date of Birth:	
Date of PAR-Q Completion:	

Researcher Name:_______________________________________

Researcher Signature: _______________________________________

Date: __________________

Appendix E: G*Power Sample Size Calculation Graph.



Appendix F: Example of Classifying Resistance Training Status.

Example of Classifying Resistance Training Status (Beachle & Earle, 2008 – p.384).					
Resistance Training Background					
Resistance Training Status	***Current Programme***	***Training Age***	***Frequency (per week)***	***Training Stress***	***Technique, Experience & Skill***
Beginner (untrained)	Not training of just began training	<2 months	1-2	None or low	None or minimal
Novice (reasonably resistance-trained)	Currently training	2-6 months	1-2	low	Basic
Intermediate (moderately resistance-trained)	Currently training	6-12 months	2-3	Medium	Moderate
Advanced (well resistance-trained)	Currently training	>1 year	3-4	High	High

Appendix G: Pre-Intervention Mobility Assessment.

Pre-Intervention Mobility Assessment.	
Mobility Movement	**Repetitions**
Bodyweight Y-Squats	10
Arm Circles	10 forwards & 10 backwards
Single-Leg Bodyweight Romanian Deadlift	5 per leg
Half-Squat Overhead Reach	10
Bodyweight Reverse Lunge & Twist	5 per leg
Toe Touch-to-Hip Extension	10
Bodyweight Lateral Lunge & Twist	5 per leg
Hip Rotations	10 per side
Scorpions	10

Appendix H: Resistance Training Warm-Up Procedure.

The following warm-up was performed before every strength and conditioning session to ensure the participants were not only primed for optimal performance within each session but also to improve mobility, flexibility and to prevent the possibility of injury. Utilising the circuit below using just an empty barbell allowed the participants to experience certain exercises with a low load or bodyweight to become familiar with the movement patterns of the exercise. Dynamic movements rather than static stretches were utilised for each warm-up routine mainly because for activities that require speed and power, a dynamic movements offer greater performance benefits compared to static stretching or no warm-up (McMillian, Moore, Hatler & Taylor, 2006). The warm-up was performed as a circuit in the order stated below:

Exercise	**Repetitions**	**Tempo**	**Intensity**
Front Squat	5	3 1 1	Empty Barbell
Overhead Press	5	3 1 1	Empty Barbell
Back Squat	5	3 1 1	Empty Barbell
Overhead Reverse Lunge	5 per leg	3 1 1	Empty Barbell
Romanian Deadlift	10	3 1 1	Empty Barbell
Barbell Row	5	3 1 1	Empty Barbell
Pull-Up	5	3 1 1	Bodyweight
Yoga Push-Up	5	3 1 2	Bodyweight

Appendix I: Intervention Resistance Training Programmes.

Contrast Training Programme:

Exercise	Repetitions	Tempo	Intensity	Rest (Seconds)	Sets
Back Squat	3	2 0 X	90% 1-RM	240	3
Jump-Squat	3	2 0 X	40% 1-RM	240	3
Bench Press	3	2 0 X	90% 1-RM	240	3
Bench Press Throw	3	2 0 X	40% 1-RM	230	3

Maximal Strength Training Programme:

Exercise	Repetitions	Tempo	Intensity	Rest (Seconds)	Sets
Back Squat	3	2 0 X	90% 1-RM	240	6
Bench Press	3	2 0 X	90% 1-RM	240	6

Training Session Key:

Exercise	Repetitions	Tempo	Intensity	Rest (Seconds)	Sets
Back Squat	3	2 0 X	90% 1-RM	240	3

Exercise: Name and order of the exercise to be performed.

Repetitions: A repetition is one complete motion through the exercise, for example, one repetition of the back squat begins by taking the bar off the rack, squatting down until knee and hip-joints parallel to the ground before returning to an upright standing position.

- 3 repetitions – number repetitions completed is 3

Tempo: The pace at which the repetitions should be performed at or the time for a static exercise to be held for.

- 2 0 X – Lower the weight over 2 seconds (eccentric phase), with no pause at the bottom before performing the concentric phase as explosively as possible.

Intensity: The amount of weight to use or time to work for the exercise.

- 90% 1 RM – weight used is 90% of the athlete's 1-repetition maximum.

Rest: The exact amount of time to rest between sets of exercises.

- 240 Seconds – athlete rests for 240 seconds (4 minutes) between each set of an exercise.

Sets: A number of repetitions to be performed together in a cyclic fashion.

Appendix J: Participant Resistance Training Recovery Guide.

Title of Project: The effects of 4 weeks of contrast training versus maximal strength training on punch force in 20-30 year old male amateur boxers.

Name of Researcher: Edward Stanley

Guide to Recovery from Resistance Training:

Foam Rolling:

To reduce muscular soreness, massaging the following areas with a foam roller is recommended for alleviating discomfort:

- Triceps.
- Latissimus Dorsi.
- Gluteus Maximus.
- Hamstrings.
- Quadriceps.
- Iliotibial Band.

Foam rolling major muscle groups after a resistance training session can assist in flushing waste products from the muscle fascia whilst also enhancing blood flow to the rolled area (Cressey & Fitzgerald, 2008).

Static Stretches:

- Triceps.
- Latissimus Dorsi.
- Deltoids.
- Pectorals.
- Gluteus Maximus.
- Adductors.
- Hip Flexors.
- Hamstrings.
- Quadriceps.

These stretches can assist in alleviating muscular soreness as well as enhancing muscular flexibility if performed regularly (Alter, 1998).

Contrasting Baths/Showers:

- 30 seconds hot.
- 30 seconds cold.
- Alternated for 5 – 10 minutes.

Contrast water therapy (contrasting baths/showers) is effective in reducing and improving the recovery of functional deficiencies that result from delayed onset muscular soreness (DOMS), as opposed to passive recovery alone (Vaile, Gill & Blazevich, 2007).

Appendix K: SPSS Normality of Distribution & Equal Variance Test Results.

Variable	Normality of Distribution (Shapiro-Wilk Test)	Equal Variance (Levene Test)
Body mass PRE	0.479	0.14
Jab PRE	0.713	0.684
Rear-hand cross PRE	0.575	0.235
Back squat PRE	0.118	0.888
Bench press PRE	0.740	0.458

Pre-Training Body Mass Normality of Distribution:

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BM Pre	.145	20	.200*	.957	20	.479

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Pre-Training Body Mass Equal Variance:

Test of Homogeneity of Variances

BM Pre

Levene Statistic	df1	df2	Sig.
.039	1	18	.846

Pre-Training 1-RM Normality of Distribution:

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BS Pre	.171	20	.126	.924	20	.118
BP Pre	.103	20	.200*	.969	20	.740

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Pre-Training 1-RM Equal Variance:

Test of Homogeneity of Variances				
	Levene Statistic	df1	df2	Sig.
BS Pre	.197	1	18	.662
BP Pre	.287	1	18	.599

Pre-Training Punch Force Normality of Distribution:

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Jab Pre	.121	20	.200*	.968	20	.713
Rear Pre	.106	20	.200*	.962	20	.575

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Pre-Training Punch Force Equal Variance:

Test of Homogeneity of Variances				
	Levene Statistic	df1	df2	Sig.
Jab Pre	1.293	1	18	.270
Rear Pre	2.247	1	18	.151

Appendix L: SPSS Body Mass Analysis Data.

Two-Way Repeated Measures ANOVA Test Output:

Tests of Within-Subjects Effects						
Measure: MEASURE_1						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Trials	Sphericity Assumed	2.601	1	2.601	20.453	.000
	Greenhouse-Geisser	2.601	1.000	2.601	20.453	.000
	Huynh-Feldt	2.601	1.000	2.601	20.453	.000
	Lower-bound	2.601	1.000	2.601	20.453	.000
Trials * Group	Sphericity Assumed	.000	1	.000	.000	1.000
	Greenhouse-Geisser	.000	1.000	.000	.000	1.000
	Huynh-Feldt	.000	1.000	.000	.000	1.000
	Lower-bound	.000	1.000	.000	.000	1.000
Error(Trials)	Sphericity Assumed	2.289	18	.127		
	Greenhouse-Geisser	2.289	18.000	.127		
	Huynh-Feldt	2.289	18.000	.127		
	Lower-bound	2.289	18.000	.127		

Tests of Between-Subjects Effects					
Measure: MEASURE_1					
Transformed Variable: Average					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	264810.529	1	264810.529	1980.566	.000
Group	980.100	1	980.100	7.330	.014
Error	2406.681	18	133.705		

Marginal Means:

1. Group				
Measure: MEASURE_1				
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	86.315	2.586	80.883	91.747
2	76.415	2.586	70.983	81.847

2. Trials

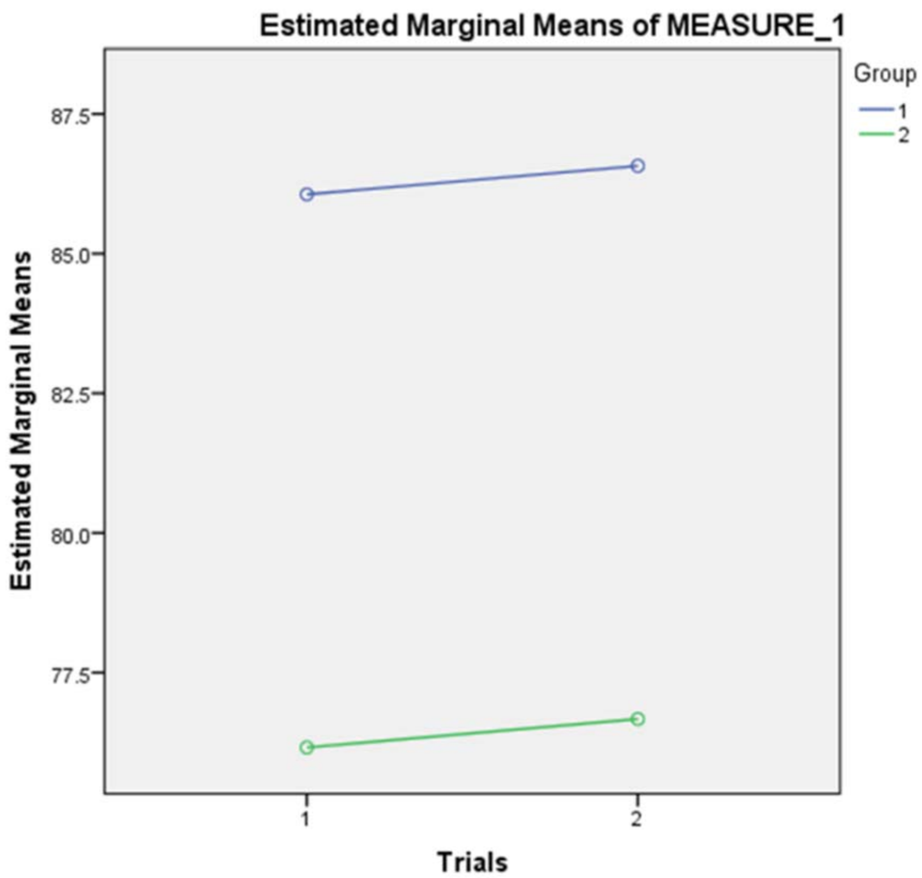
Measure: MEASURE_1

Trials	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	81.110	1.829	77.267	84.953
2	81.620	1.829	77.777	85.463

3. Group * Trials

Measure: MEASURE_1

Group	Trials	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	86.060	2.587	80.625	91.495
	2	86.570	2.587	81.136	92.004
2	1	76.160	2.587	70.725	81.595
	2	76.670	2.587	71.236	82.104



Appendix M: SPSS Punch Force Analysis Data

JAB Two-Way Repeated Measures ANOVA Test Output:

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Trials	Sphericity Assumed	55.225	1	55.225	534.723	.000
	Greenhouse-Geisser	55.225	1.000	55.225	534.723	.000
	Huynh-Feldt	55.225	1.000	55.225	534.723	.000
	Lower-bound	55.225	1.000	55.225	534.723	.000
Trials * Group	Sphericity Assumed	4.096	1	4.096	39.660	.000
	Greenhouse-Geisser	4.096	1.000	4.096	39.660	.000
	Huynh-Feldt	4.096	1.000	4.096	39.660	.000
	Lower-bound	4.096	1.000	4.096	39.660	.000
Error(Trials)	Sphericity Assumed	1.859	18	.103		
	Greenhouse-Geisser	1.859	18.000	.103		
	Huynh-Feldt	1.859	18.000	.103		
	Lower-bound	1.859	18.000	.103		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

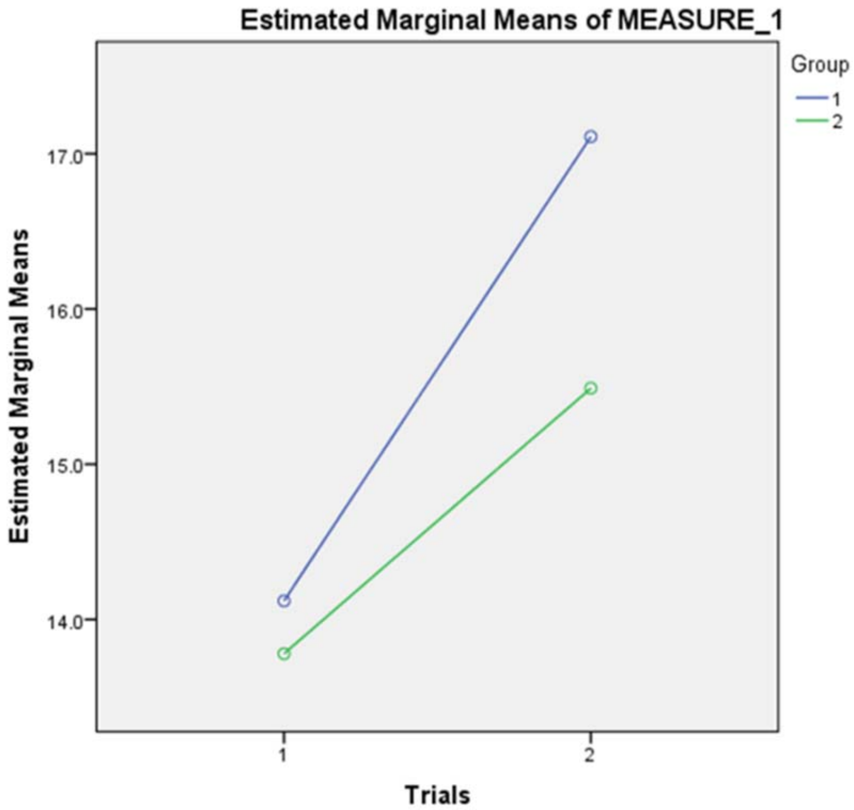
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	9150.625	1	9150.625	1223.427	.000
Group	9.604	1	9.604	1.284	.272
Error	134.631	18	7.480		

Marginal Means:

1. Group				
Measure: MEASURE_1				
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	15.615	.612	14.330	16.900
2	14.635	.612	13.350	15.920

2. Trials				
Measure: MEASURE_1				
Trials	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	13.950	.411	13.088	14.812
2	16.300	.459	15.336	17.264

3. Group * Trials					
Measure: MEASURE_1					
Group	Trials	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	14.120	.581	12.900	15.340
	2	17.110	.649	15.746	18.474
2	1	13.780	.581	12.560	15.000
	2	15.490	.649	14.126	16.854



REAR-HAND CROSS Two-Way Repeated Measures ANOVA Test Output:

Tests of Within-Subjects Effects						
Measure: MEASURE_1						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Trials	Sphericity Assumed	65.536	1	65.536	381.146	.000
	Greenhouse-Geisser	65.536	1.000	65.536	381.146	.000
	Huynh-Feldt	65.536	1.000	65.536	381.146	.000
	Lower-bound	65.536	1.000	65.536	381.146	.000
Trials * Group	Sphericity Assumed	5.929	1	5.929	34.482	.000
	Greenhouse-Geisser	5.929	1.000	5.929	34.482	.000
	Huynh-Feldt	5.929	1.000	5.929	34.482	.000
	Lower-bound	5.929	1.000	5.929	34.482	.000
Error(Trials)	Sphericity Assumed	3.095	18	.172		
	Greenhouse-Geisser	3.095	18.000	.172		
	Huynh-Feldt	3.095	18.000	.172		
	Lower-bound	3.095	18.000	.172		

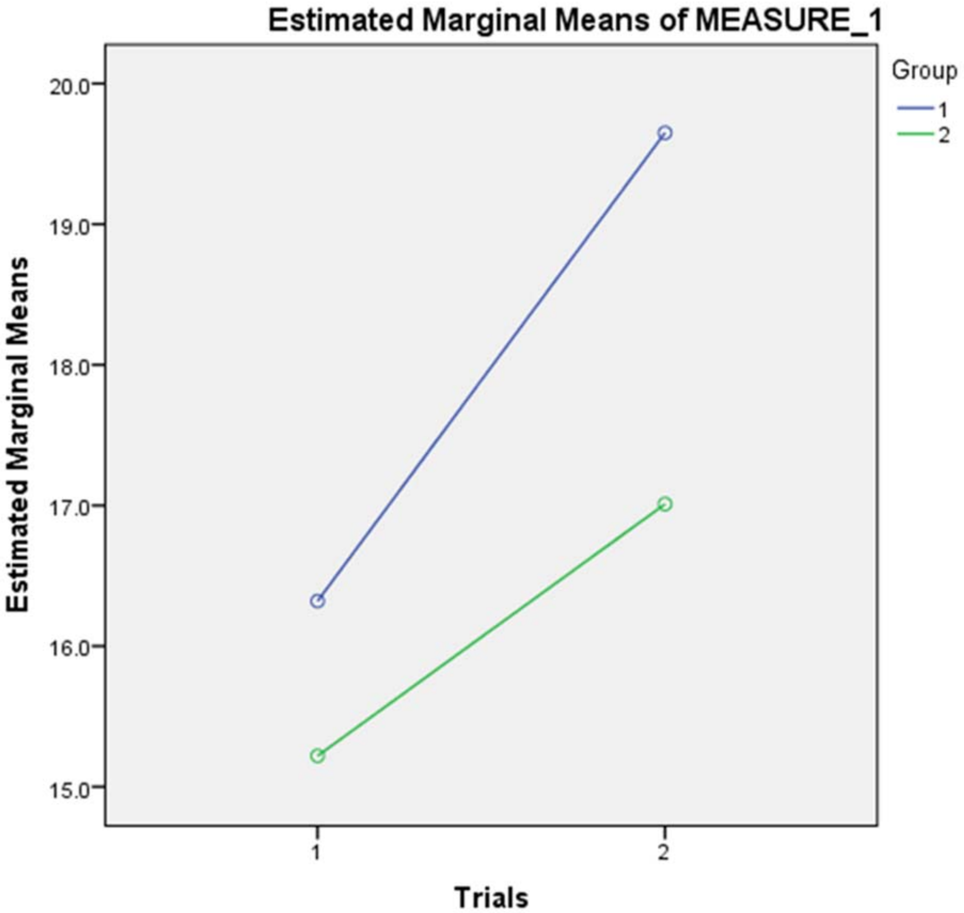
Tests of Between-Subjects Effects					
Measure: MEASURE_1					
Transformed Variable: Average					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	11628.100	1	11628.100	1259.126	.000
Group	34.969	1	34.969	3.787	.067
Error	166.231	18	9.235		

Marginal Means:

1. Group				
Measure: MEASURE_1				
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	17.985	.680	16.557	19.413
2	16.115	.680	14.687	17.543

2. Trials				
Measure: MEASURE_1				
Trials	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	15.770	.448	14.829	16.711
2	18.330	.519	17.239	19.421

3. Group * Trials					
Measure: MEASURE_1					
Group	Trials	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	16.320	.633	14.989	17.651
	2	19.650	.734	18.107	21.193
2	1	15.220	.633	13.889	16.551
	2	17.010	.734	15.467	18.553


Estimated Marginal Means of MEASURE_1
Group
1
2
20.0
19.0
18.0
17.0
16.0
15.0
Estimated Marginal Means
1
2
Trials

Appendix N: SPSS One-Repetition Maximum (1-RM) Analysis Data.

BACK SQUAT Two-Way Repeated Measures ANOVA Test Output:

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Trials	Sphericity Assumed	3940.225	1	3940.225	598.263	.000
	Greenhouse-Geisser	3940.225	1.000	3940.225	598.263	.000
	Huynh-Feldt	3940.225	1.000	3940.225	598.263	.000
	Lower-bound	3940.225	1.000	3940.225	598.263	.000
Trials * Group	Sphericity Assumed	133.225	1	133.225	20.228	.000
	Greenhouse-Geisser	133.225	1.000	133.225	20.228	.000
	Huynh-Feldt	133.225	1.000	133.225	20.228	.000
	Lower-bound	133.225	1.000	133.225	20.228	.000
Error(Trials)	Sphericity Assumed	118.550	18	6.586		
	Greenhouse-Geisser	118.550	18.000	6.586		
	Huynh-Feldt	118.550	18.000	6.586		
	Lower-bound	118.550	18.000	6.586		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

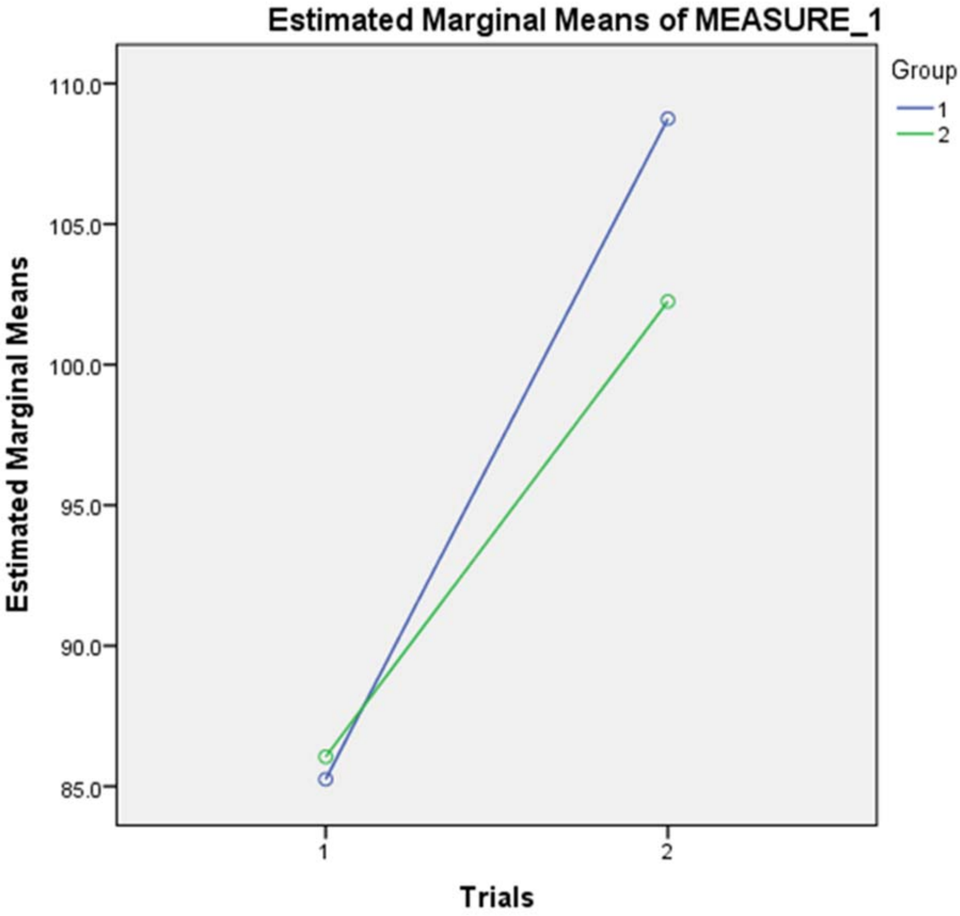
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	365383.225	1	365383.225	1162.499	.000
Group	81.225	1	81.225	.258	.617
Error	5657.550	18	314.308		

Marginal Means:

1. Group				
Measure: MEASURE_1				
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	97.000	3.964	88.671	105.329
2	94.150	3.964	85.821	102.479

2. Trials				
Measure: MEASURE_1				
Trials	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	85.650	2.791	79.786	91.514
2	105.500	2.873	99.464	111.536

3. Group * Trials					
Measure: MEASURE_1					
Group	Trials	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	85.250	3.947	76.957	93.543
	2	108.750	4.063	100.214	117.286
2	1	86.050	3.947	77.757	94.343
	2	102.250	4.063	93.714	110.786



BENCH PRESS Two-Way Repeated Measures ANOVA Test Output:

Tests of Within-Subjects Effects						
Measure: MEASURE_1						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Trials	Sphericity Assumed	2805.625	1	2805.625	160.960	.000
	Greenhouse-Geisser	2805.625	1.000	2805.625	160.960	.000
	Huynh-Feldt	2805.625	1.000	2805.625	160.960	.000
	Lower-bound	2805.625	1.000	2805.625	160.960	.000
Trials * Group	Sphericity Assumed	180.625	1	180.625	10.363	.005
	Greenhouse-Geisser	180.625	1.000	180.625	10.363	.005
	Huynh-Feldt	180.625	1.000	180.625	10.363	.005
	Lower-bound	180.625	1.000	180.625	10.363	.005
Error(Trials)	Sphericity Assumed	313.750	18	17.431		
	Greenhouse-Geisser	313.750	18.000	17.431		
	Huynh-Feldt	313.750	18.000	17.431		
	Lower-bound	313.750	18.000	17.431		

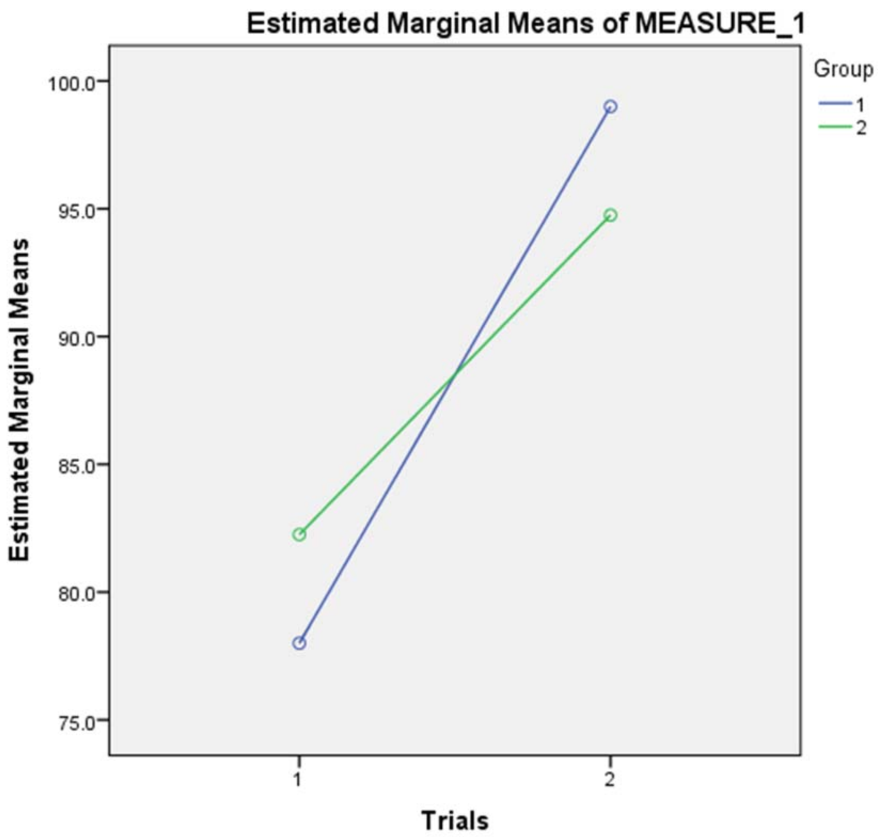
Tests of Between-Subjects Effects					
Measure: MEASURE_1					
Transformed Variable: Average					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	313290.000	1	313290.000	1178.520	.000
Group	.000	1	.000	.000	1.000
Error	4785.000	18	265.833		

Marginal Means:

1. Group				
Measure: MEASURE_1				
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	88.500	3.646	80.841	96.159
2	88.500	3.646	80.841	96.159

2. Trials				
Measure: MEASURE_1				
Trials	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	80.125	2.803	74.236	86.014
2	96.875	2.511	91.599	102.151

3. Group * Trials					
Measure: MEASURE_1					
Group	Trials	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	78.000	3.964	69.672	86.328
	2	99.000	3.552	91.538	106.462
2	1	82.250	3.964	73.922	90.578
	2	94.750	3.552	87.288	102.212


Estimated Marginal Means of MEASURE_1
Group
1
2
100.0
95.0
90.0
85.0
80.0
75.0
Estimated Marginal Means
1
2
Trials

Post-Hoc Test Output:

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	CTJABpre - CTJABpost	-2.9900	.5877	.1859	-3.4104	-2.5696	-16.087	9	.000
Pair 2	CTREARpre - CTREARpost	-3.3300	.7304	.2310	-3.8525	-2.8075	-14.418	9	.000
Pair 3	MSJABpre - MSJABpost	-1.7100	.2601	.0823	-1.8961	-1.5239	-20.788	9	.000
Pair 4	MSREARpre - MSREARpost	-1.7900	.3929	.1242	-2.0710	-1.5090	-14.409	9	.000
Pair 5	CTBSpre - CTBSpost	-23.5000	2.9345	.9280	-25.5992	-21.4008	-25.324	9	.000
Pair 6	MSBSpre - MSBSpost	-16.2000	4.2111	1.3317	-19.2124	-13.1876	-12.165	9	.000
Pair 7	CTBPpre - CTBPpost	-21.0000	7.9232	2.5055	-26.6679	-15.3321	-8.381	9	.000
Pair 8	MSBPpre - MSBPpost	-12.5000	2.6352	.8333	-14.3851	-10.6149	-15.000	9	.000

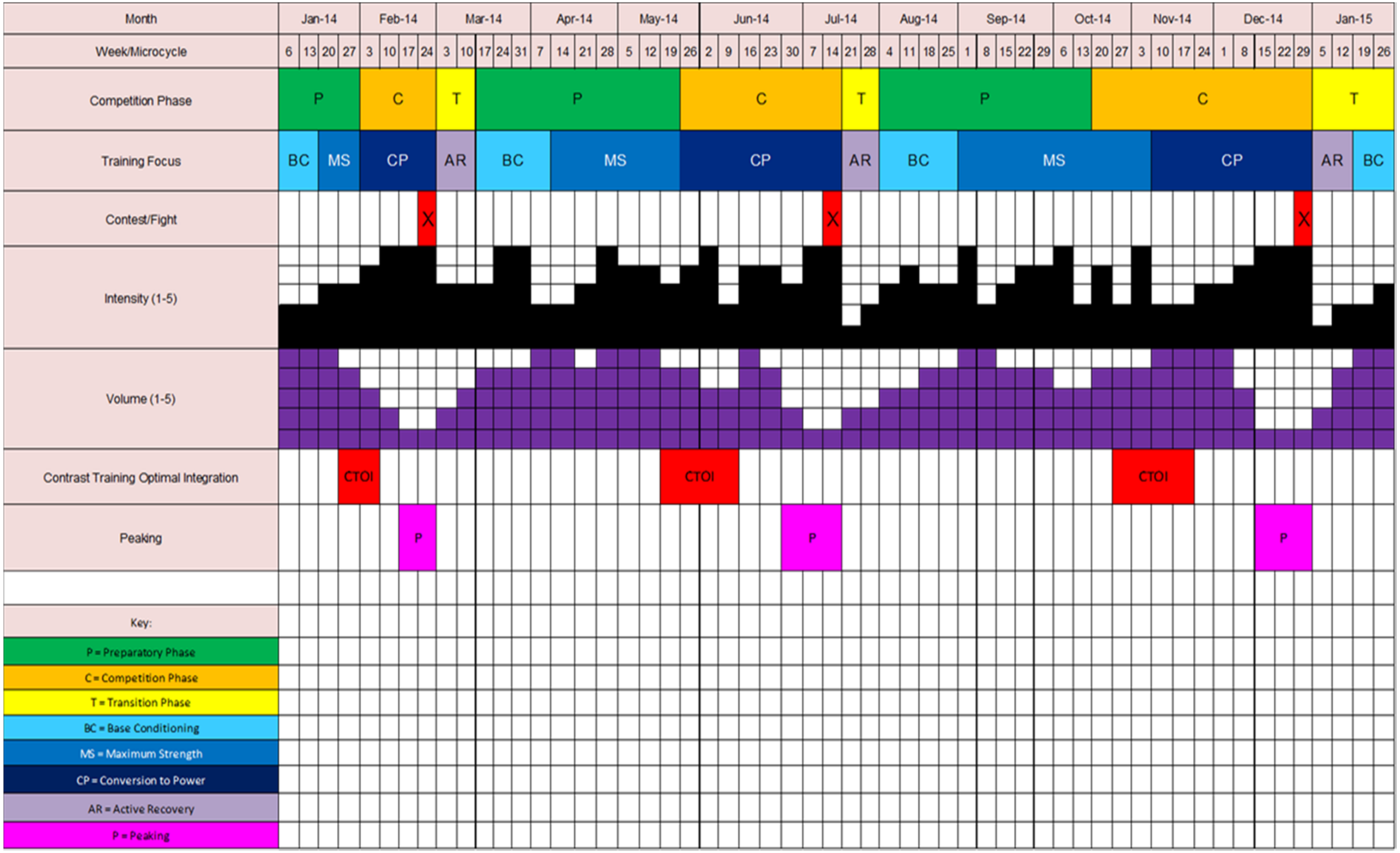
Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
JabPost	Equal variances assumed	2.832	.110	1.765	18	.095	1.6200	.9178	-.3083	3.5483
	Equal variances not assumed			1.765	16.214	.096	1.6200	.9178	-.3236	3.5636
RearPost	Equal variances assumed	3.425	.081	2.542	18	.020	2.6400	1.0387	.4578	4.8222
	Equal variances not assumed			2.542	12.477	.025	2.6400	1.0387	.3865	4.8935
BSpost	Equal variances assumed	.998	.331	1.131	18	.273	6.5000	5.7458	-5.5714	18.5714
	Equal variances not assumed			1.131	17.272	.273	6.5000	5.7458	-5.6080	18.6080
BPpost	Equal variances assumed	.219	.645	.846	18	.409	4.2500	5.0229	-6.3026	14.8026
	Equal variances not assumed			.846	16.576	.410	4.2500	5.0229	-6.3680	14.8680

Appendix O: HDT Punch Force Reliability Details

Although indicating good repeatability between punch force trials, normality tests yielded a high degree of non-normality (P< .0005), yet, values also demonstrated a high percentage of perfect agreement across all three trials for most participants. Because there was little variation between punch force measures, the normality tests may have indicated non-normality if a punch score was not consistent and so may have distorted the data. A surprising outcome was that the punch force trials were highly consistent and lacked considerable variation, perhaps the result of two justifications. Firstly, according to the manufacturer, The HDTs measurement capacity ranges from 3g to 40g, measuring force in 0.5 increments. Subsequently, concerns may surface surrounding validity as punch forces recorded when using the sensor may not be completely accurate due to the 'rounding up' of scores to the nearest 0.5 g. Therefore, although significant increases were exhibited by both training groups within the present study, as no previous authors have tested the sensitivity of the device, results should be observed with caution. Secondly, due to the boxers each having a minimum of 2 years boxing training, the proficiency of the boxers within the testing may have played a role in the consistent results produced. The ability to throw punches with technical proficiency over repeated attempts may explain why punch force trials had high percentages of perfect agreement as muscular recruitment when punching becomes more efficient with experience (Lockwood & Tant, 1997). Although these results indicate high test-retest reliability for jab and rear-hand cross punch force using a HDT sensor, further research is required to verify HDT sensor reliability and validity.

Reliability of the HDT device in testing punching force		
Punch type	*Jab*	*Rear-hand cross*
Typical error	0.16	0.17
Coefficient of variation	1.01%	0.96%
Normality of results (Shapiro-Wilk)	*Trial 1* – 0.412	*Trial 1* – 0.272
	Trial 2 – 0.298	*Trial 2* – 0.131
	Trial 3 – 0.235	*Trial 3* – 0.145
Difference in mean values between trials 1 & 2 (%)	0.63%	0.56%
Difference in mean values between trials 2 & 3 (%)	0.62%	0%
Identical punch force values across all trials (%)	60%	65%

Appendix P: Amateur Boxing Periodised Training Programme



Raw Data

Raw Data A: Baseline Participant Anthropometric Details

Raw Data B: Participant One-Repetition Maximum (1-RM) Data.

Raw Data C: Contrast Training (CT) Participant Jab & Rear-Hand Cross Punch Force Data.

Raw Data D: Maximal Strength Training (MST) Participant Jab & Rear-Hand Cross Punch Force Data.

Raw Data E: HDT Device Punch Force Reliability Test Data.

Raw Data F: Participant Signed Consent Forms.

Raw Data G: Participant Signed Physical Activity Readiness Questionnaires (PAR-Q).

Raw Data A: Baseline Participant Anthropometric Details

Participant	***Age***	***Stature (metres)***	***Body mass (pre-training – kg)***	***Preferred boxing stance***	***Boxing experience (years)***	***Resistance training experience (years)***
CT 1	28	180	79.7	Orthodox	6	0.5
CT 2	21	188	90.3	Orthodox	5	0.8
CT 3	25	186	85	Orthodox	4	0.4
CT 4	27	172	80.2	Orthodox	5	0.9
CT 5	29	176	73.4	Orthodox	2	0.9
CT 6	21	191	98.3	Orthodox	2	0.4
CT 7	24	188	92.8	Orthodox	5	0.6
CT 8	30	182	88.2	Orthodox	7	0.7
CT 9	29	180	90	Orthodox	9	0.7
CT 10	28	176	82.7	Orthodox	5	0.7
MST 1	25	180	75.9	Orthodox	3	0.4

MST 2	27	174	71.5	Orthodox	3	0.5
MST 3	24	182	75.3	Orthodox	4	0.8
MST 4	26	169	65.6	Orthodox	3	0.9
MST 5	29	191	98.9	Orthodox	6	0.9
MST 6	27	175	72.6	Orthodox	9	0.8
MST 7	25	179	75.9	Orthodox	10	0.8
MST 8	25	180	80.1	Orthodox	4	0.7
MST 9	24	176	76.3	Orthodox	5	0.9
MST 10	29	172	69.5	Orthodox	7	0.5

Raw Data B: Participant One-Repetition Maximum (1-RM) Data

Participant	Back squat 1-RM (pre-intervention - kg)	Back squat 1-RM (post-intervention - kg)	Bench press 1-RM (pre-intervention - kg)	Bench press 1-RM (post-intervention - kg)
CT 1	77.5	100	65	100
CT 2	85	115	72.5	100
CT 3	100	125	90	110
CT 4	75	95	75	97.5
CT 5	82.5	105	87.5	105
CT 6	115	135	100	110
CT 7	67.5	90	60	90
CT 8	75	97.5	65	80
CT 9	85	110	80	92.5
CT 10	90	115	85	105
Mean	*85.3*	*108.8*	*78.0*	*99.0*
Standard Deviation	*13.1*	*13.4*	*12.1*	*9.0*
Percentage Increase (pre- to post-training intervention)	*27.5%*		*26.9%*	

MST 1	80	95	85	97.5
MST 2	80	97.5	80	95
MST 3	80	90	75	85
MST 4	82.5	100	72.5	85
MST 5	110	130	105	120
MST 6	90	105	85	92.5
MST 7	95.5	105	95	110
MST 8	90	105	80	92.5
MST 9	82.5	105	85	95
MST 10	70	90	60	75
Mean	*86.1*	*102.3*	*82.3*	*94.8*
Standard Deviation	*10.4*	*10.9*	*11.6*	*12.1*
Percentage Increase (pre- to post-training intervention)	*18.8%*		*15.1%*	

Raw Data C: Contrast Training (CT) Participant Jab & Rear-Hand Cross Punch Force Data

Punch type & trial	**Participant**									
Pre-intervention	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Jab 1	13	15	16	12	15.5	17	11.5	12	13	16
Jab 2	13	15	16	11.5	15.5	17	11.5	12	13.5	16
Jab 3	13	14.5	16	12.5	15	17	12	12.5	13	16
Jab 4	13.5	15	16	12	15	17	11.5	12	13.5	16
Jab 5	13	15.5	16	11.5	15	17	12	12	13	16
Average	*13.1*	*15*	*16*	*11.9*	*15.2*	*17*	*11.7*	*12.1*	*13.2*	*16*
St Dev	*0.2*	*0.3*	*0*	*0.4*	*0.2*	*0.0*	*0.2*	*0.2*	*0.2*	*0*
Post-intervention	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Jab 1	15.5	17.5	19	15	18	22	14	15	16	20
Jab 2	15.5	17.5	19	15	18	22	14	15	16	20

Jab 3	15.5	17.5	19	15	18	22	14	15	16	20
Jab 4	15.5	17.5	19	15	18	22	14	15	16	20
Jab 5	15.5	18	19	15	18	21.5	14	15	16	20
Average	*15.5*	*17.6*	*19*	*15*	*18*	*21.9*	*14*	*15*	*16*	*20*
St Dev	*0*	*0.2*	*0*	*0*	*0*	*0.2*	*0*	*0*	*0*	*0*
Pre- to post-training increase	*14.1 ± 1.8 to 17 ± 2.1 = 21.2%*									
Pre-intervention	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Rear-hand cross 1	15.5	17	19	13	16.5	21	14	14	15.5	17.5
Rear-hand cross 2	15.5	17.5	19	13	16.5	21	14	14	15.5	17
Rear-hand cross 3	15	17	19	13.5	16.5	21	14	14	15.5	17.5
Rear-hand cross 4	15	17	18.5	12.5	16.5	21	14	14.5	15.5	17.5
Rear-hand cross 5	16	17	19	13.5	17	21	14	14	15.5	18
Average	*15.4*	*17.1*	*18.9*	*13.1*	*16.6*	*21*	*14*	*14.1*	*15.5*	*17.5*
Standard Deviation	*0.4*	*0.2*	*0.2*	*0.4*	*0.2*	*0.0*	*0.0*	*0.2*	*0.0*	*0.3*

Post-intervention	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Rear-hand cross 1	18	20	23	16	20	26	17.5	17	18	20
Rear-hand cross 2	18	20	23	16	20	26	17.5	17	18	20
Rear-hand cross 3	18.5	20	23	16	20	26	17.5	17	18.5	20
Rear-hand cross 4	18.5	20	23	16	20	26	17.5	17.5	18	21
Rear-hand cross 5	18	21	23	16	20	26	17.5	17.5	18	20.5
Average	*18.2*	*20.2*	*23*	*16*	*20*	*26*	*17.5*	*17.2*	*18.1*	*20.3*
Standard Deviation	*0.2*	*0.4*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0.2*	*0.4*
Pre- to post-training increase	*16.3 ± 2.3 to 19.7 ± 2.8 = 20.8%*									

Raw Data D: Maximal Strength Training (MST) Participant Jab & Rear-Hand Cross Punch Force Data

Punch type & trial	**Participant**									
Pre-intervention	MST1	MST2	MST3	MST4	MST5	MST6	MST7	MST8	MST9	MST10
Jab 1	14	13	14	12	16	14.5	15	14	15	10
Jab 2	14	13	14	12	16	14.5	15	14	15	10
Jab 3	14	13.5	14	12	16	14.5	15	14	15	10
Jab 4	14	13	15	12	16	14.5	15	14	15	10
Jab 5	14	13	14	12	16	14.5	15	14	15	10
Average	*14*	*13.1*	*14.2*	*12*	*16*	*14.5*	*15*	*14*	*15*	*10*
Standard Deviation	*0*	*0.2*	*0.4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Post-intervention	MST1	MST2	MST3	MST4	MST5	MST6	MST7	MST8	MST9	MST10
Jab 1	15.5	14.5	15.5	14	18	16	16.5	15.5	17	12
Jab 2	15.5	14.5	15.5	14	18	16	16.5	15.5	17	12

Jab 3	16	14.5	15.5	14	18	16	16.5	15.5	17	12
Jab 4	15.5	14.5	16	14	18	16	16.5	15.5	17	12
Jab 5	16	14.5	16	14	18	16	16.5	15.5	17	12
Average	*15.7*	*14.5*	*15.7*	*14*	*18*	*16*	*16.5*	*15.5*	*17*	*12*
Standard Deviation	*0.24*	*0*	*0.24*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Pre- to post-training increase	*13.8 ± 1.6 to 15.5 ± 1.6 = 12.3%*									
Pre-intervention	MST1	MST2	MST3	MST4	MST5	MST6	MST7	MST8	MST9	MST10
Rear-hand cross 1	15	14	16	13.5	17	15.5	16	15	17	12.5
Rear-hand cross 2	15.5	14	16	13.5	17	15.5	16	15	17	12.5
Rear-hand cross 3	15.5	14	16	13.5	17	15.5	16	15	17	12.5
Rear-hand cross 4	15	15	16	13.5	17	16	16	15	17	12.5
Rear-hand cross 5	15	14	16.5	13.5	17	16	16	15	17	12.5
Average	*15.2*	*14.2*	*16.1*	*13.5*	*17*	*15.7*	*16*	*15*	*17*	*12.5*
Standard Deviation	*0.2*	*0.4*	*0.2*	*0*	*0*	*0.2*	*0*	*0*	*0*	*0*

Post-intervention	MST1	MST2	MST3	MST4	MST5	MST6	MST7	MST8	MST9	MST10
Rear-hand cross 1	17	16	17.5	15.5	19	17.5	18	16	19	15
Rear-hand cross 2	17	16	17.5	15.5	19	17.5	18	16	18.5	15
Rear-hand cross 3	17	16	17.5	15.5	19	17.5	18	16	18.5	15
Rear-hand cross 4	17	16	17.5	15.5	19	17.5	18	16	18.5	15
Rear-hand cross 5	17	16	17.5	15.5	18.5	17.5	18	16	19	15
Average	*17*	*16*	*17.5*	*15.5*	*18.9*	*17.5*	*18*	*16*	*18.7*	*15*
Standard Deviation	*0*	*0*	*0*	*0*	*0.2*	*0*	*0*	*0*	*0.2*	*0*
Pre- to post-training increase	*15.2 ± 1.4 to 17 ± 1.3 = 11.8%*									

Raw Data E: HDT Device Punch Force Reliability Test Data

Participant	Jab trial 1	Jab trial 2	Jab trial 3	Rear-hand cross trial 1	Rear-hand cross trial 2	Rear-hand cross trial 3
1	17	17	17.5	19.5	20	20
2	15	15	15	17	17	16.5
3	15.5	15.5	15.5	17.5	17	17.5
4	18	18	18	19	19	19
5	12	12	12.5	14.5	15	14.5
6	14	14	14	17	17	17
7	17	17	17	19	19	19
8	15.5	15.5	15.5	18	18	17.5
9	12	12	12.5	13	13	13
10	15	15	15	16.5	16.5	16.5
11	14	14	14	16	16	16
12	22	22	22	25.5	26	26

13	19	19	18.5	22	22	22
14	20	20.5	20.5	21	21	21
15	16.5	16.5	16.5	18	18	18
16	14	14	14	15.5	15.5	15.5
17	15	15	15.5	16.5	16.5	16.5
18	17	17	17	18	18	18
19	13	13.5	13.5	14	14.5	14.5
20	15	15	15	17	17	17
Mean ± SD	*15.8 ± 2.5*	*15.9 ± 2.5*	*16.0 ± 2.4*	*17.7 ± 2.8*	*17.8 ± 2.8*	*17.8 ± 2.9*
Jab trial 1-2 = 0.63%						
Jab trial 2-3 = 0.62%						
Jab % with identical values = 60%						
Rear-hand cross trial 1-2 = 0.56%						
Rear-hand cross trial 2-3 = 0%						
Rear-hand cross % with identical values = 65%						